NASA

BIOMEDICAL APPLICATION TEAM PROGRAM

Applications of Aerospace Technology in Biology and Medicine

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RESEARCH TRIANGLE INSTITUTE
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PREFACE

This report covers the 15 September 1969 to 14 March 1970 activities of the NASA Biomedical Application Team at the Research Triangle Institute. These activities were performed in accomplishing Tasks A through F, Statement of Work, NASA Contract No. NASW-1950. Accomplishment of Task G, Supplementary Efforts, is reported separately. This work was performed in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the technical direction of Dr. James N. Brown, Jr. Full-time members of the team and other RTI staff members who participated in the project are Dr. F. T. Wooten, Mr. Ernest Harrison, Dr. G. S. Hayne and Mr. B. W. Crissman. Assistance from other members of the RTI staff was obtained on an as-needed basis.

Medical consultants who contributed significantly to the project are Dr. E. A. Johnson, Duke University Medical Center, Durham, North Carolina; Dr. G. S. Malindzak, Jr., Wake Forest University, Bowman Gray School of Medicine, Winston-Salem, North Carolina; William Z. Penland, National Cancer Institute, Bethesda, Maryland; Prof. Hal Becker, Tulane School of Medicine, New Orleans, Louisiana; and Dr. Myron Youdin, Institute of Rehabilitation Medicine, New York, New York.

ABSTRACT

This report presents the results of the activities of the NASA Biomedical Application Team at the Research Triangle Institute. This experimental program in technology transfer was supported by NASA Contract No. NASW-1950 for the reporting period 15 September 1969 to 14 March 1970. The RTI Biomedical Application Team is a multidisciplinary team of scientists and engineers acting as an information and technology interface between NASA and individuals, institutions, and agencies involved in biomedical research and clinical medicine. At present, the RTI Biomedical Application Team is staffed by: Dr. J. N. Brown, Jr., Electrical Engineer; Dr. F. T. Wooten, Electrical Engineer; Mr. Ernest Harrison, Materials Scientist; Dr. G. S. Hayne, Physicist; and Mr. B. W. Crissman, Geophysicist. Additionally, the team draws upon the capability of other members of the RTI staff as needed.

Nine medical organizations are presently participating in the RTI Biomedical Application Team program: Duke University Medical Center, Durham, North Carolina; the Medical School of the University of North Carolina, Chapel Hill, North Carolina; the University of North Carolina Dental School and Dental Research Center, Chapel Hill, North Carolina; the Bowman Gray School of Medicine, Winston-Salem, North Carolina; the North Carolina State University, Raleigh, North Carolina; the Institute of Rehabilitation Medicine of New York University Medical Center, New York, New York; the National Cancer Institute, Bethesda, Maryland, Tulane School of Medicine, New Orleans, Louisiana; and Brookdale Hospital Center, Brooklyn, New York.

The accomplishments of the Research Triangle Institute Biomedical Application Team during the reporting period are as follows: The team has identified 54 new problems for investigation, accomplished eleven transfers of technology, closed 59 old problems, and on 14 March 1970 had a total of 64 problems under active investigation.

Significant transfers of technology include a new material for heart pacemaker electrodes developed from space antenna research as well as uses of computer correlation techniques in cardiovascular research.

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LIST OF ABBREVIATIONS

BATeam	Biomedical Application Team
COSMIC	Computer Software Management and Information Center
IAA	International Aerospace Abstracts
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
NCSTRC	North Carolina Science and Technology Research Center
RDC	Regional Dissemination Center
RTI	Research Triangle Institute
SIE	Science Information Exchange
STAR	Science and Technical Aerospace Abstracts
TATeam	Technology Application Team
TUO	Technology Utilization Officer
WESRAC	Western Regional Applications Center
ARAC	Aerospace Research Applications Center
I/O	Input/output (facilities)
MAP	Machine Assembly Program
FAP	Fortran Assembly Program

1.0 INTRODUCTION

1.1 Introductory Comments

Significant benefits are to be gained by applying the scientific and technological results of federally funded research and development (R and D) programs to other problem areas than those for which they were created. The size of the national investment in R and D programs and the very significant technological achievements which have been realized in the past decade demand that an effort be made to apply the results of these programs to the social, economic, environmental, and health-related sectors of our society.

The National Aeronautics and Space Administration (NASA) has been a leader and innovator in the establishment, study, and assessment of technology transfer programs since that agency was established by the Space Act of 1958. Through its Tech Brief, Special Publication, Technology Survey, and Regional Dissemination Center programs, NASA has been successful in transferring the results of aerospace R and D to an impressive number of nonaerospace applications.

More recently, NASA has established a program which uses an active, directed transfer methodology. In this program, NASA has established three Biomedical Application Teams (BATeams) and four Technology Application Teams (TATeams) at not-for-profit research institutions. The methodology is active in that specific problems are identified and specified through direct contact with potential users of aerospace technology. The process is directed in that the teams interact only with potential users who are involved in reaching selected national objectives. These include biology and medicine for the BATeams and air pollution control, water pollution control, marine sciences, mine safety, and criminalistics for the TATeams. The three Biomedical Application Teams which have been established by NASA are located at the following institutions:

Research Triangle Institute
P. O. Box 12194
Research Triangle Park, North Carolina 27709

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228

This report covers the accomplishments and activities of the Biomedical Application Team located at the Research Triangle Institute for the period 15 September 1969 to 14 March 1970. In the remainder of Section 1.0 are presented discussions of BATeam objectives and methodology.

1.2 Biomedical Application Team Program

The specific objectives of NASA's Biomedical Application Team program are as follows:

(1) Transfer of a maximum number of specific items of aerospace technology to medicine in order to solve or partially solve problems in biology and medicine;

(2) Analyze, refine, and document the manner in which the transfer of aerospace technology to medicine is accomplished in order to enhance the understanding of active processes of technology transfer; and,

(3) Motivate potential adopters of aerospace technology in medicine, organizations involved in generating advanced technology, and individuals who can influence technology transfer programs to become actively involved in more comprehensive technology utilization programs.

A description of the Biomedical Application Team program can be facilitated by reference to Figure 1. Basically, the team represents an interface between medical investigators and clinicians and the body of science and technology that has resulted from the nation's aerospace R and D effort. The team attempts

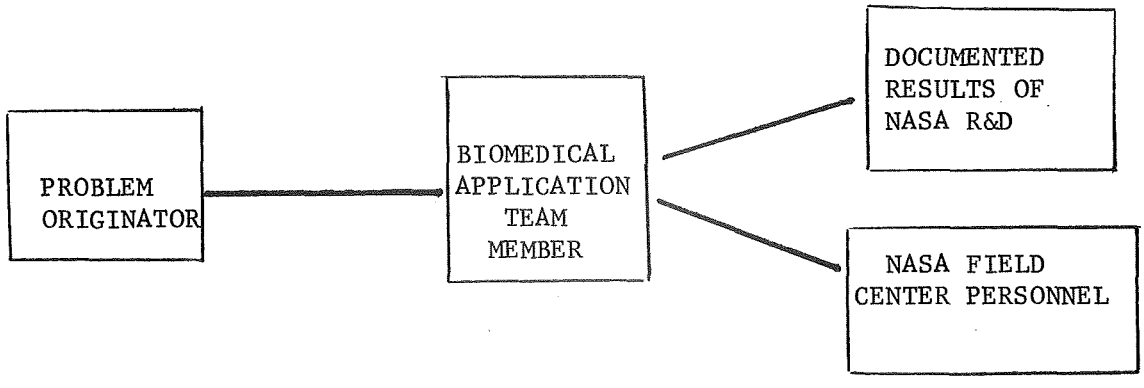

Figure 1. Possible Mechanisms for Transfer of Technology.

to couple the technological problems and requirements in medicine with relevant aerospace technology and, in particular, NASA-generated technology. The problems and requirements are those being encountered in medical research programs to improve general medical practice. The team actively engages in identifying these problems through direct contact with medical staffs or

"problem originators." The identification and specification of medical problems is followed by a search for technology which may be relevant to solutions to these problems.

Generally, technology relevant to specific problems is identified through two approaches: (1) manual and computer searching of the aerospace information bank created by NASA as part of its R and D effort and (2) direct contact with the engineering and scientific staff at NASA Field Centers. Technology representing potential solutions to problems is channeled through the team to the problem originator for evaluation and implementation as a solution to his problem. Alternatively, and less frequently, the team establishes a contact between the problem originator and NASA Field Center personnel and the transfer of information between NASA and the medical field becomes more direct. The more direct the transfer, the more relevant, accurate, and complete is this transfer. Thus, the BATeam attempts to create these direct interchanges whenever appropriate and feasible.

Assistance to the problem originator in implementing solutions to problems is an important part of the BATeam program. This assistance may take any one of a number of different forms. Direct assistance to the problem originator in his efforts to implement a solution is frequently involved. During this reporting period NASA's Technology Utilization Division has established a reengineering or adaptive engineering program in the School of Engineering of the University of Virginia which is now assisting in this program by adapting NASA technology to the needs of a limited number of problem originators. This adaptive engineering program is directed by Dr. M.L. McCartney of the Division of Biomedical Engineering. The BATeams are responsible for identifying the NASA technology which is potentially a solution to a specific problem and for specifying the changes required in this technology. This allows the teams to demonstrate that the technology is in fact a solution to the problem and allows the problem originator to make use of the NASA technology in his work.

The successful transfer of information on aerospace technology to an individual or group in the medical field followed by successful implementation of the technology with resulting benefits to the accomplishment of some medical objective is called a "technology transfer." Also included in the definition of technology transfer is the constraint that the medical application and objective involved in the transfer be different from the aerospace application and objective for which the technology was originally developed. Thus, the accomplishment of technology transfers is indeed a difficult and long term objective. This objective should be distinguished from that objective involved in a program to enhance the diffusion or broad utilization of demonstrated applications of technology. Technology transfer involves crossing what may be thought of as an "application or objective barrier" and it involves complete evaluation of the new application; diffusion involves neither of these requirements.

A specific methodology is applied by the Biomedical Application Team in its efforts to affect technology transfers. This methodology is discussed in the following section.

1.3 Methodology

The methodology used by the BATeam consists of four basic steps: problem definition, identification of relevant technology, evaluation of relevant technology,

and documentation. This methodology can be better understood, however, if it is separated into the steps shown in Figure 2. These steps are described in the following paragraphs.

Problem screening -- Effective problem screening is at least as important to the success of the BATeam program as any of the operational steps identified in Figure 2. Analysis of the RTI team's accomplishments over a period of three and one-half years indicates clearly that a very significant fraction of the problems which have been investigated unsuccessfully could have been rejected very early in discussions with the problem originators. Problem selection criteria have been developed with the objective being to increase the average probability that a technology transfer can be accomplished for problems accepted by the teams. At present the following criteria are being applied:

> Solving the problem would enhance medical diagnosis, treatment, or patient care to the extent that implementation and adoption would be rapid.
>
> OR
>
> The problem has been encountered in an ongoing research program and is impeding progress of that program.
>
> OR
>
> Some unique characteristics of the problem or problem originator indicates that investigating the problem will enhance the overall BATeam program.
>
> AND
>
> Solving the problem is given high priority by the problem originator.
>
> AND
>
> The problem is one of at most two being investigated with an individual problem originator. (This is violated only in the case of mission-oriented group efforts.)

Problems which do not satisfy these criteria are rejected. Problems may also be rejected following partial completion of the next step, problem definition.

Problem Definition -- The objective of this step is to define precisely and accurately the characteristics of the technology required to solve a problem. It is important that all necessary constraints are included and equally important that no unnecessary constraints are included in characterizing the required technology. In many cases, following the characterization of required technology, it is found that the problem should be rejected or closed for any of a number of reasons. These reasons include, as examples, the following: (1) the problem can be solved using commercially available equipment, (2) the problem cannot be solved and an entirely different approach is indicated, (3) the real problem is medical and not technical in nature, and (4) the requirements cannot be

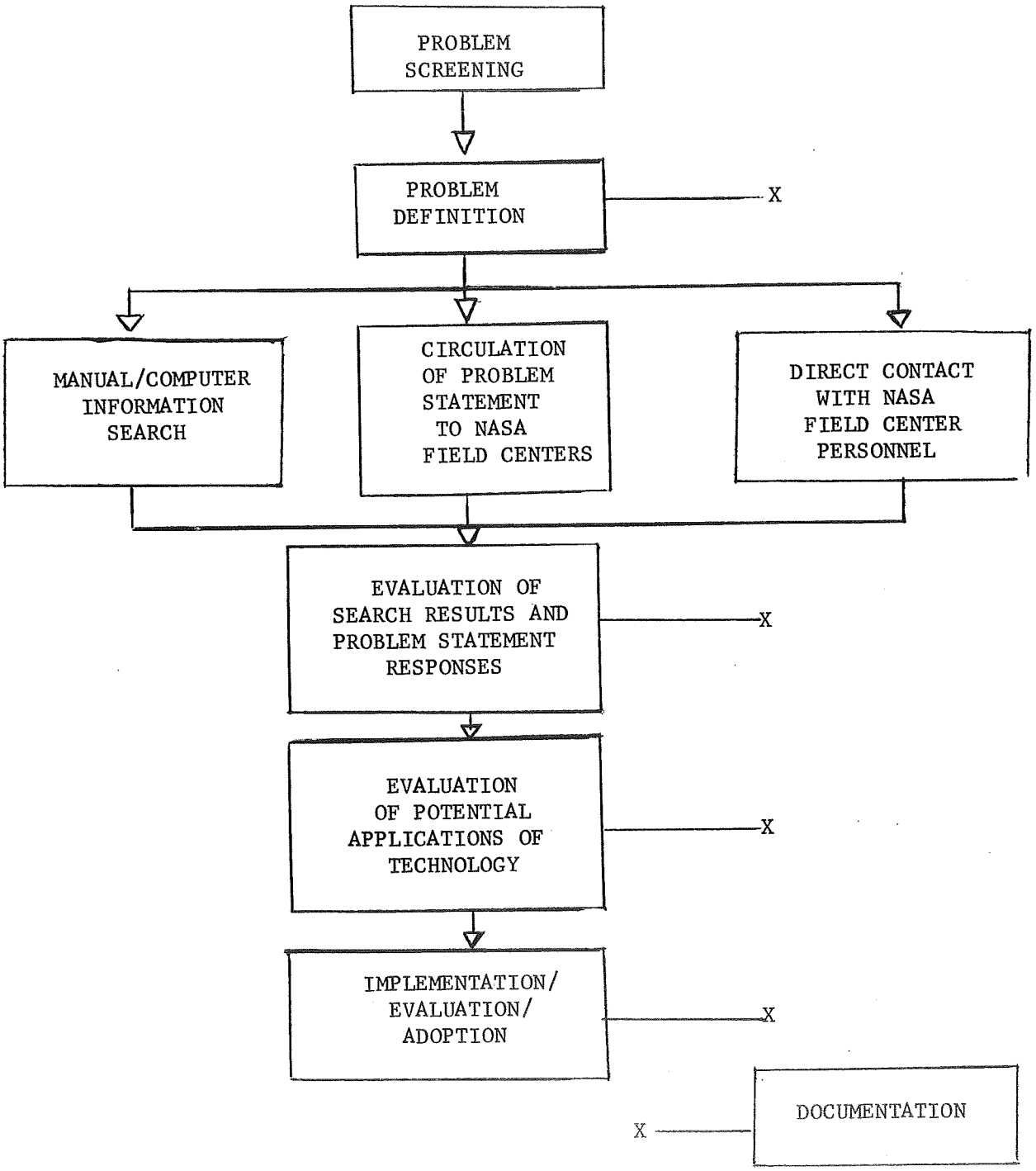

Figure 2. Flow Chart of Biomedical Application Team Transfer Methodology.

specified because insufficient information exists on the objective involved.

The end result of problem definition is the preparation of a problem statement. This statement, to be complete, must contain: (1) a complete characterization of what is required to solve the problem, and (2) the related medical problem or objective and the benefits to be realized by solving the problem.

Identification of relevant aerospace technology -- Aerospace technology which may be relevant to the solution of a problem is identified by three approaches. First, a manual or computer search is made of the aerospace information bank. These searches are made at one of NASA's six Regional Dissemination Centers (RDC). The RDC used by the RTI BATeam is the North Carolina Science and Technology Research Center (NCSTRC) located in Research Triangle Park, North Carolina. The information which can be assessed through the RDC's bank consists of the approximately 700,000 documents, articles, and translations which have been abstracted in the Science and Technology Abstract Reports (STAR) and the International Aerospace Abstracts (IAA). Second, problem statements are circulated to engineers and scientists at NASA Field Centers who may be able to identify relevant technology and suggest possible solutions to problems. These statements are circulated in a highly selective manner with the distribution being determined by the BATeam, Technology Utilization Officers (TUO) at the NASA Field Centers, and other individuals at the Field Centers. Third, the team in some cases contacts individuals at the Field Centers directly without circulating problem statements. This is done when a team member can identiry a relatively few individuals at the Field Centers who should have a good overview of all work being done which is related to the requirements of a specific problem.

First evaluation -- All potentially relevant technology identified in the preceding step is evaluated by the BATeam to determine if a potential solution to a specific problem has been found. Those items of technology which represent potential solutions to problems are presented to problem originators along with available supporting data and information. Any required reengineering and details of implementing the potential solutions are discussed with the problem originator.

Second evaluation -- The problem originator must then evaluate potential solutions. His decision to implement a proposed solution will depend upon a number of factors: (1) his assessment of the validity of the proposed potential solution, (2) the cost of implementing the potential solution, (3) the potential benefits to be gained, etc. The team may be asked to supply additional information and technical details in this evaluation.

Implementation, final evaluation, adoption -- The final step in the transfer process is the implementation and experimental evaluation of potential solutions. The team is available for assistance in this step when required. Hopefully, when a potential solution is shown to be a valid

solution to a problem, this solution is adopted by the problem originator and the transfer is complete.

Documentation -- Documentation is an integral part of the BATeam methodology; it is involved at most steps in the process, as indicated in Figure 2. Documentation allows analysis of the transfer process and assessment of the program in general. At present, the teams report on a weekly, monthly, and semiannual schedule. Effective communication is required between BATeams and potential problem originators and other individuals who are in a position to make use of information resulting from transfers accomplished by the BATeams.

1.4 Biomedical Application Team Composition and Participating Medical Institutions

The RTI BATeam is a multidisciplinary group of engineers and scientists. The educational backgrounds of the group are in physics and electrical engineering; their experience includes industrial, educational, and research at both basic and applied levels. The individuals who presently make up the RTI team are:

Name	Background	Duty
Dr. J. N. Brown, Jr.	Electrical Engineer	Team Director
Dr. F. T. Wooten	Electrical Engineer	Project Leader
Mr. E. Harrison	Materials Scientist	Solution Specialist
Dr. G. S. Hayne	Physicist	Solution Specialist
Mr. B. W. Crissman	Geophysicist	Documentation

The experience and special capabilities of other individuals at RTI and particularly the Engineering and Environmental Sciences Division are frequently used in the BATeam program on an as-needed basis.

At present, nine medical institutions are participating in the RTI BATeam program. These institutions are as follows:

Duke University Medical Center, Durham, North Carolina;
(Including Veterans' Administration Hospital, Durham, North Carolina);

Bowman Gray School of Medicine of the Wake Forest University, Winston-Salem, North Carolina;

University of North Carolina Medical School, Chapel Hill, North Carolina;

University of North Carolina Dental School, Chapel Hill, North Carolina;

Institute of Rehabilitation Medicine, New York University, New York, New York;

North Carolina State University, Raleigh, North Carolina;

Tulane University Medical School, New Orleans, Louisiana;

National Cancer Institute of the National Institutes of Health, Bethesda, Maryland;

Brookdale Hospital Center, Multiphasic Health Screening Clinic, Brooklyn, New York.

The RTI team is assisted at various stages of the transfer process by consultants who are on the medical staff at participating institutions. These consultants or communicators coordinate BATeam activities at their institutions and assist team members primarily in problem definition and evaluation of potential solutions. At present, the following individuals are consultants to the RTI team:

Name	Specialty
Dr. E. A. Johnson Duke University Medical Center	Cardiac Physiology
Dr. George S. Malindzak Bowman Gray School of Medicine of the Wake Forest University	Physiology
Professor Hal C. Becker Tulane University Medical School	Radiology
Mr. William Z. Penland National Cancer Institute	Engineering
Mr. Myron Youdin Institute of Rehabilitation Medicine New York University	Engineering

In addition to the above, Dr. T. C. Pilkington and Dr. F. L. Thurstone, Biomedical Engineering Division, Duke University, are assisting the RTI team in investigating the potential for transferring NASA digital computer applications programs to applications in medicine.

In addition, individuals at the following institutions have participated on certain special problems:

Medical College of Virginia, Richmond, Virginia;
National Institute of Mental Health, Washington, D. C.;
University of Mississippi Medical School, Jackson, Mississippi;
National Communicable Disease Center, Atlanta, Georgia;
Louisiana State University School of Medicine, New Orleans, Louisiana.

Problems at each institution are coded by a letter and number symbol (e.g. DU-49), and the coding for each institution is as follows:

DU - Duke University School of Medicine
NCSU - North Carolina State University
UNC - University of North Carolina Medical School
UNCD - University of North Carolina Dental School
WF - Bowman Gray School of Medicine at Wake Forest University
IRM - Institute of Rehabilitation Medicine at New York University
TU - Tulane University School of Medicine
NCI - National Cancer Institute
BH - Brookdale Hospital Center
MCV - Medical College of Virginia
LSU - Louisiana State University School of Medicine
NIMH - National Institute of Mental Health
CP - Computer software type problem
MISC - Miscellaneous

1.5 Definition of Terms

In the Biomedical Application Team program, a number of terms have evolved which describe the elements and processes in this program. Because of their number and unfamiliarity to the majority of readers, these terms are listed and defined in this section for easy and quick reference.

Problem originator -- An individual actively involved in an effort to reach a specific objective in biology or medicine and faced with a specific technological problem which is impeding progress toward that objective.

Participating institution -- A medically oriented educational institution, hospital, medical center, or government agency, having as one of its organizational objectives the improvement of medical health care for the general public or a particular sector of the general public and having agreed to participate actively in the Biomedical Application Team program.

Consultant -- A member of the biomedical staff at a participating user institution who has committed a fraction of his time and effort to assist the Biomedical Application Team in identifying and coordinating visits with appropriate problem originators at his institution, in understanding and specifying problems in biology and medicine, and in evaluating technological solutions to problems.

Biomedical Application Team (BATeam) -- A multidisciplinary group of engineers and scientists engaged in problem solving activities in biology and medicine with the specific objectives of effecting the transfer of aerospace technology to solve or aid in solving problems in medicine, and of understanding and optimizing the methodology for effecting such transfers of technology. The methodology used by the BATeam involves (1) problem selection, definition, and specification; (2) identification of potential solutions to problems by manual and computer information searching, circulation of problem statements to NASA Field Centers, and contacts with NASA engineers and scientists; (3) evaluation of potential solutions; (4) implementation and adoption,

by problem originators, of aerospace technology as solutions or partial solutions to medical problems; and (5) documentation.

Problem -- A specific and definable technological requirement that cannot be satisfied with commercially available equipment or through the application of information or knowledge available to the problem originator through routinely used information channels. Problems for investigation are accepted by the team subject to the problem screening criteria which are discussed in Section 1.3. Within the context of the Biomedical Application Team program, it is explicitly assumed that problems investigated by the team are problems which are impeding progress toward reaching an objective which involves improving medical and health care services for one or more sectors of the general public.

Technology transfer -- The implementation and adaption of an item of aerospace technology by a problem originator to solve or aid in solving a problem in biology or medicine. The medical application involved is one which is different from that application for which the aerospace technology was originally developed.

Problem statement -- A concise written statement of a problem which is used for communicating (1) to the information search specialists sufficient details to allow a computer search to be performed and (2) to NASA engineers and scientists sufficient information to motivate them to consider possible solutions to the problem and allow them to determine if and in what way they can assist in solving the problem.

Computer information search -- A computerized information search of the aerospace information bank established by NASA and made available through six Regional Dissemination Centers in the United States. This information bank consists of the approximately 700,000 documents which have been indexed and abstracted in the Science and Technical Abstract Reports (STAR) and International Aerospace Abstracts (IAA). Applications engineers at these centers design search strategies using information in problem statements. These search strategies allow one to identify those documents in the information bank which are relevant to the solution of a specific problem.

Impact -- The transfer of information to a problem originator with the result that he changes what he is doing in a way that enhances his progress toward a medical objective. An impact is thus analogous to a technology transfer except that one or more of the requirements for a technology transfer is not satisfied.

2.0 SUMMARY AND ANALYSIS OF TECHNOLOGY TRANSFERS

2.1 Introduction and Summary

During the period from September 1969 to March 1970, the RTI Biomedical Application Team documented and reported to NASA eleven technology transfers and eight impacts. Of eight potential technology transfers, two were active as of March 14, 1970. These results are summarized in Table 1 on page 12.

As defined in Section 1.5, a technology transfer is "the implementation and adaption of an item of aerospace technology by a problem originator to solve or aid in solving a problem in biology or medicine. The medical application involved is one which is different from that application for which the aerospace technology was originally developed." Also, in the Introduction, an impact is defined as "the transfer of information to a problem originator with the result that he changes what he is doing in a way that enhances his progress toward a medical objective. An impact is thus analogous to a technology transfer except that one or more of the requirements for a technology transfer is not satisfied."

The definition of a technology transfer set forth in this report is not new; it has been proposed and discussed frequently, but rarely applied rigorously. In December 1970, the RTI team defined and started reporting impacts for a specific reason. The reader should keep in mind that although the transfer as defined here can be conceptualized easily it has been realized only rarely indeed. Thus, the impact was introduced to allow more of the positive outputs of the BATeam to be documented and reported, and at the same time allow the term transfer to be applied rigorously according to the definition given above.

Introduction of the impact allows one to more clearly state the objective of the BATeam program. That objective is the accomplishment of transfers and not impacts. The impact, although of value, lies somewhere between abject failure and soaring success.

It is stressed that most of the technology transfers reported here were documented before impacts were introduced and some of the cases would, as of the end of the reporting period, be classified as impacts rather than transfers. Such cases are reported here in order to avoid confusion as they have been reported in monthly reports to NASA. These will, however, be clarified in the following section.

2.2 Discussion and Analysis of Transfers

In this section the transfers accomplished during the reporting period are characterized. The specific aspects which are discussed are qualitative, impact areas, source of technology transferred, method of identifying the relevant technology, and time required to investigate the problem.

In nine of the eleven cases reported, the relevant technology has been or is being implemented. The two exceptions, WF-31 and WF-33, should have been reported as impacts and will not be discussed further as transfers. The reengineering and implementation required in the remaining nine cases is being accomplished by the problem originators.

Table 1. Transfers and Impacts Accomplished During the Period from September 1969 to March 1970 and Potential Transfers Documented and Active as of March 14, 1970.

Transfers

DU-45	Low Velocity Anemometry
DU-46	Electrode Material for Pacemakers
IRM-3	An Improved Spiral Brace
IRM-7	A Material for Use in Direct Contact with the Blood Which Exhibits Reduced Clotting Characteristics
IRM-8	Low Temperature Lubricant for Microtomes
IRM-20	Prevention of Orthostatic Hypotension
NCSU-6	Analysis Techniques for EEG Data
WF-31	A Servo-Controlled System to Measure the Partial Pressure of Oxygen and Carbon Dioxide in Expired Gases and to Control the Operation of Respirators
WF-33	Application of Biotelemetry Units to Intensive Care Areas
WF-69	Correlation Techniques
VU-1	Improved Material for Percutaneous Tubes for Blood Dialysis

Impacts

WF-68	Electrodes for Exercise EKG
WF-70	Underwater Telemetry
IRM-1	Determination of Brace Socket Pressure
IRM-4	An Improved Material for Construction of Self-Adjusting Braces
IRM-10	Methods of Measuring Calcium

Table 1. (Continued)

	Impacts (Continued)
IRM-15	Effect of Environmental Extremes on Skeletal Calcium
IRM-21	An Improved Splinting and Cost Material
IRM-26	A Means of Presetting Prosthetic Hands to Grip Objects with a Desired Force
	Potential Transfers (March 1970)
WF-56	A Fluid Pressure Calibration System
IRM-23	A Respiration Alarm

Two transfers involve novel applications of a new biocompatible material, vitreous carbon, developed for NASA by North American Rockwell. In both cases, Mr. Jim Benson of Biocarbon (Tarzana, California) supplied the problem originators with special configurations of the material which allowed them to implement the solutions identified by the BATeam. One transfer, VU-1, involves use of the material as cannula implanted in patients requiring dialysis. The other, IRM-7, involves the development of an implantable blood flow meter.

Two transfers, WF-69 and NCSU-6, involve the application of signal analysis techniques resulting from aerospace R and D programs. The specific applications are in basic research programs in the cardiovascular and neurophysiological areas respectively. The relevant information in transfer WF-69 was identified during discussions at Marshall Space Flight Center (MSFC) between the problem originator, Dr. Fritz Krause and Mr. Andrew Ellner of MSFC. These individuals at MSFC were identified by Mr. James T. Richards of NASA's Technology Utilization Division. Transfer IRM-8 has resulted in the problem originator adopting a solid-film lubricant developed for aerospace applications and now commercially available as the appropriate lubricant for microtomes operating at temperatures to -80°C.

A basic investigation into biological mechanisms of temperature control has profited from information obtained from the aerospace information bank and given to the problem originator of DU-45. This information allowed the problem originator to choose a hot wire anemometer as the optimum approach to an instrumentation problem and to design and implement the instrument.

Transfer DU-46 resulted in the problem originator and a member of the Biomedical Engineering Division at Duke University collaborating in the implementation of a new pacemaker heart electrode using Nitinol, a material developed for use in aerospace antennas and studied under NASA contract by Goodyear Aerospace Corporation. The "mechanical memory" characteristic of this material may allow the implantation of pacemakers without major surgery. This material was identified through problem statement responses from Mr. William Klapp of NASA's Lewis Research Center, Mr. D. J. Winslow of NASA's Marshall Space Flight Center; and Mr. J. G. Fisher of NASA's Jet Propulsion Laboratory. Mr. W. J. Buehler of the Naval Ordnance Laboratory supplied material samples for preliminary tests.

Transfer IRM-3 has resulted in the design and implementation of a new spiral leg brace for patients requiring leg braces. The solution was identified by the team member in the problem definition phase of the BATeam methodology. The original problem was to identify a new stronger material for the brace; available materials are sufficiently strong for the redesigned brace.

Transfer IRM-20 through the use of a NASA-designed and fabricated G-suit allowed a patient at the Institute of Rehabilitation Medicine to tolerate a vertical position although she could not normally do so because of the occurrence

of orthostatic hypotension. The suit was made available by Mr. John Samos of NASA's Langley Research Center. Unfortunately, treatment has been terminated because of psychological problems.

Of the nine solutions discussed in the preceding paragraphs, eight involved aerospace technology; six involved NASA technology. The ninth solution resulted from the process of problem definition by the BATeam.

The relevant technologies involved in these transfers were identified by a number of different mechanisms. Two resulted from computer searches at NCSTRC; one from a manual search at NCSTRC. One transfer resulted from NASA Field Center personnel responding to a circulated problem statement; one resulted from a response to a problem statement appearing in an RTI monthly report. Three transfers resulted from the team's knowledge of aerospace technology and of the individuals to contact for assistance.

The average time required to accomplish the eleven transfers (not including follow-up time) was 9.36 months. Two of the transfers involved unusual lengths of time, 22 and 23 months. If only the other nine transfers are considered, the average time involved is considerably reduced to 6.4 months. This represents a slight increase in the time (5.25 months) required to accomplish transfers, as reported in a previous RTI report [Ref. 1]. This minor variation may be attributed to the fact that the previous report covered a larger sample of transfers and no significance is attributed to the increase. However, the importance of making a fast transfer of technology requires that careful consideration be given to these statistics.

3.0 SUMMARY AND ANALYSIS OF PROBLEMS INVESTIGATED BY BIOMEDICAL APPLICATION TEAM

The importance of an analysis of the problems investigated by the BATeam to an assessment of the effectiveness of the team in applying transfer methodology is second only to an analysis of the team's success in achieving technology transfers. In this section the problems accepted, rejected, and closed during the reporting period and the problems active at the end of this period are summarized. These data are then analyzed primarily to determine the effectiveness of problem screening by the team and to qualitatively assess the potential impact which could result from solving active problems.

3.1 Problems Accepted, Rejected, and Closed

During the reporting period, the RTI BATeam accepted 54 problems, rejected 10 problems, and closed 59 problems. Problem statements for all problems accepted with the exceptions of NCI-8, IRM-25, and MISC-3 have been prepared and are presented in Appendix D. Thus the backlog of active problems was reduced by five problems during this period. These data are present in Table 2 for each participating institution. In the table the change in the number of active problems, ΔP, at each institution is also shown. It is clear that team activities at three of these user institutions (Bowman Gray School of Medicine at Wake Forest University, the University of North Carolina Dental School, and the Institute of Rehabilitation Medicine of New York University) are decreasing rapidly. The total change in the number of active problems at these three institutions was a decrease of 35 during the reporting period. The decrease at the University of North Carolina is due to the lack of an effective interface; there is no consultant at that institution. The Institution of Rehabilitation Medicine at New York University is not large enough to support the level of activity reached approximately one year ago. The change at Wake Forest University reflects two factors. First, the BATeam consultant, Dr. Malindzak, has contacted all individuals and groups with which he is familiar at that institution. Second, a relatively large number of problems have been closed for reasons which should have caused the problems to have been rejected.

The greatest increase in the number of active problems has occurred at three institutions which have become participating institutions during the last six months. These institutions are the Brookdale Hospital Center Multiphasic Screening Demonstration unit, the National Cancer Institute, and the Tulane University Medical School.

Table 2. Problems Accepted, Rejected, and Closed During Period from September 1969 to March 1970.

	Problems Accepted	Problems Rejected	Problems Closed	ΔP
Wake Forest University	11	1	25	-14
Duke University	7	4	4	+3
Brookdale Hospital	6		0	+6
Tulane University	5	2	0	+5
National Cancer Institute	6		0	+6
North Carolina State University	4		2	+2
Institute of Rehabilitation Medicine	4	1	12	-8
University of North Carolina				
Medical School	2		2	0
Dental School	0		13	-13
Louisiana State University	1		0	
Medical College of Virginia	1	1	0	
National Institute of Mental Health	1		0	
Miscellaneous	2		1	
Computer-related	4		0	+4

While the data in Table 2 are interesting and give an accurate picture of redirection of team effort, it is more instructive to analyze the reasons these problems have been closed. This analysis allows one to assess the success of the team in problem-screening and in accomplishing technology transfers. Table 3 gives 11 categories of reasons for closing problems and the percentages of problems closed in each of the categories for both the reporting period, September 1969 to March 1970, and the two-year period from June 1967 to June 1969.

Consider the data applicable to the two-year period first. Of the problems closed, 20 percent were the result of accomplishing technology transfers. As noted in a previous report, [Ref. 1] the majority of the problems closed nonproductively fell into categories B and I. It should have been possible to reject those in category B through increased attention to evaluation of the problem originator's motivation. Better understanding of the elements of problem definition should have eliminated those problems closed in category I.

Consider now the problems closed during the period from September 1969 to March 1970. Note that the percentage of problems closed in category B has been reduced by a factor of three. This is very encouraging until it is seen that this decrease is more than compensated by the very significant increase of problem closures in category K. Note that categories B and K are not completely independent and it is certainly conceivable that team members would have difficulty distinguishing between these categories in many cases. On the positive side, of the 15 problems (30 percent) closed in category K, 13 were problems from Wake Forest University and the University of North Carolina Dental School where the team's activity is being reduced. All 13 of these problems were accepted before September 1969. Thus, the large percentage of problems closed in category K does not in itself indicate that problem selection criteria have not been applied effectively. However, if the problems in category K are completely ignored, then 32 percent of the remaining problems were closed for reasons (categories B, C, D, H, I, and J) which in most of these cases should have resulted in the problems being rejected. Thus, there is considerable room for improvement in the application of problem selection criteria at the initial problem-screening phase and during problem definition.

Finally the percentage of technology transfers accomplished during the reporting period was 21 percent as compared to 20 percent in the reported two-year period. Additionally, 10 percent of the problems closed are in a new category called "impacts". Thus, in 31 percent of all cases inactivated during the reporting period, information of value to the problem originator was transferred.

Table 3. Summary of Problems Closed

Problem Closure Categories	Percentages of Problems Closed	
	June 1967 to June 1969	Sept. 1969 to March 1970
A --- Transfer accomplished.	20%	21%
B --- Researcher has no further interest in the problem.	33	10
C --- Researcher has found his own solution.	4	7
D --- As a result of personnel transfer in the medical institutions, the problem has either been closed or transferred to another institution along with the investigator and has been given a new number.	9	3
E --- No present or foreseeable future NASA technology applicable.	7	7
H --- Satisfactory solution identified by team and verified by researcher but transfer cannot be completed by researcher for reasons of economy or lack of resources.	3	6
I --- Problem as originally stated was too broad or general.	15	3
J --- Problem is too difficult; i.e., the problem as given to the RTI Biomedical Application Team is presently the focus of large expenditures of money, research, and development effort making the likelihood of success by the Biomedical Application Team low.	8	30
K --- Problem priority too low. Factors involved are cost/benefit ratio, team resources available, researcher's resources, and enthusiasm.	1	0
L --- Problem grouped under another number with other related problems.	0	
M --- Impact	0	10
Total Numbers of Problems Closed	145	68

3.2 Active Problem Status

As of 14 March 1970, the RTI Biomedical Application Team had a backlog of 65 active problems. These problems are listed in Appendix B along with a problem status designation and problem titles. The numbers of problems in each of the six stages of the transfer process are presented in Table 4 and are compared with similar data for June 1968 and June 1969. The most significant difference in these data is the increased number of problem statements circulated to NASA Field Centers. During the latter half of the reporting period, eight problem statements were circulated. These eight problem statements are presented in Appendix C. Responses to three of these problem statements have been received from NASA centers to date. Technology directly relevant to the solution of two of the problems has been identified in these responses. A meaningful analysis of this situation cannot however be made this early in the problem statement circulation cycle.

In order to facilitate a qualitative assessment of the active problems being investigated by the RTI BATeam, brief statements of the technological requirement involved in each problem and of the medical objective involved are presented in Table 5. These brief statements of the problems correspond to the "what is needed" parts of the Problem Statements in Appendixes C and D. From this table one can quickly determine the types of problems originating from each participating institution and the scope of problems being investigated by the team.

From the nature of the technological requirements one can identify two generally different types. One type of problem is characterized by a precise and specified technology gap in the medical field. Examples of this type are TU-6, TU-3, and DU-67. These problems involve the identification of a transducer, an analog signal processor, and a material respectively. In all three cases, solutions either do not exist in medical technology or the available solutions represent only partial solutions. The important aspect of this type of requirement is that it can be specified and from these specifications one can determine whether a particular transducer, approach, or material does in fact represent a solution to the problem. The second type of problem is illustrated by BH-1 through BH-3 and is characterized by the lack of specifications on what is actually required. The problem originator for these problems is asking to see what has been developed in aerospace R and D programs relevant to a medical objective. The BATeam technology transfer program is directed toward solving problems of the former type where the team can clearly identify the characteristics of technology required to solve a problem. The latter unspecified requirement is more appropriately handled by a Regional Dissemination Center. The RTI team is at present examining all active problems which are of the latter type and attempting to obtain meaningful specifications on what is required so that the team's methodology can be applied with some reasonable chance of achieving a technology transfer.

Another way of characterizing the problems being investigated by the team is to categorize them according to the medical area which is affected (impact area) if the problems are solved. This breakdown of active problems is presented in Table 6, on page 30, Impact Areas. In the table, an asterisk indicates that the problem is listed under two or more impact areas. From the table it can be seen that most of the problems being investigated by the team fall into the following categories:

Improved instrumentation and techniques for clinical diagnosis; multiphasic health screening -- 18 problems

Provision of improved rehabilitation medicine and techniques -- 8 problems

Detection and treatment of heart disease -- 9 problems

Detection and treatment of cancer -- 8 problems

Basic biological and medical research -- 15 problems

Table 4. Active Problem Status

Problem Status	Number of Problems		
	June 1968	June 1969	March 1970
A. Problem Definition	0	0	2
B. Information Searching	45	53	30
C. Problem Statement Circulation	1	0	8
D. Evaluation	19	24	23
E. Potential Transfer	2	1	2
F. Follow-up Activity	13	15	0
	80	93	65

Table 5. Brief Statements of Active Problems

BH-1 -- NASA developments in the measurement of respiratory gas volume and flow rate on patients exercising in a health screening clinic.

BH-2 -- NASA developments in the analysis of respiratory gas constituents (O_2, CO_2, N_2) for patients exercising in a health screening clinic.

BH-3 -- NASA developments in the measurements of blood pressure application for patients exercising in a health screening clinic.

BH-4 -- NASA-developed blood flow transducers for noninvasive monitoring of arterial blood flow transducer for a patient exercising in a health screening clinic.

BH-5 -- NASA-developed electrocardiogram electrodes for attachment to a patient exercising in a health screening clinic.

BH-6 -- Information and experiemental data is needed on various types of exercise tests, particularly information related to standardization of exercise tests and to definitions of normal performance for different groups within the general population.

CP-1 -- Computational techniques for data compression or data redundancy reduction to be used in health care delivery systems.

CP-2 -- (1) Theoretical elasticity and computer software developments which utilize geometrical and external force data to determine stress and strain distributions in elastic and viscous materials.
(2) Materials science software which utilizes time and spatial stress and strain distributions to characterize viscous and nonviscous material properties.

CP-3 -- A method of digital image processing is needed for performing a large number of position measurements for specified points in a sequential series of coronary angiograms.

CP-4 -- Information is needed concerning computer programming to permit asynchronous real-time data acquisition during batch processing using an IBM 1130 Model 2B computer.

DU-31 -- A catheter-mounted pressure transducer which can be inserted into chambers of the human heart for high-fidelity monitoring of blood pressure waveforms in the heart as a diagnostic tool in pediatric cardiology.

Table 5. (Cont.)

DU-47 -- A catheter-mounted pressure transducer for insertion into the urinary tract for monitoring pressure waveforms as a diagnostic tool.

DU-48 -- A flowmeter for measuring flows in the urinary tract as a diagnostic tool.

DU-58 -- A portable urine disposal system which can be mounted on the belt of patients who do not have urinary control.

DU-59 -- A temperature transducer which can be mounted on the end of a probe that is inserted into the brain of patients undergoing surgery for Parkinson's Syndrome.

DU-61 -- Improvements in image resolution and contrast in image-intensified fluoroscopy for high quality, real-time visualization of the cardiovascular system as a diagnostic tool.

DU-63 -- Method of detecting the firing of individual nerve cells without penetration of the cell wall to be used in basic research on the nervous system.

DU-65 -- A transducer for measuring changes in length of ligaments in newly-amputated knee joints and for use in basic research on ligament injuries.

DU-66 -- A transducer for measuring oxygen partial pressure in the scalp of infants during childbirth in order to reduce infant mortality.

DU-67 -- A synthetic resin which will adsorb single antigens and at a later time can be separated on the basis of specific gravity from the solutions being studied. These resins will be used in basic research on immunology.

DU-68 -- A method for producing grooves, 10 microns in width and depth with a length of several centimeters, to be used in basic research on cardiac muscle cells.

IRM-2-- An energy converter which can convert limited body or limb motions of patients with impaired limb function into useful energy to power the prosthetic devices needed to restore function to the patient.

IRM-5 -- An improved wire with increased resistance to fatigue failure and corrosion in body fluids for electrical connection to implanted devices both in humans and animals.

Table 5 (Cont.)

IRM-14 -- A motion-force amplifier system with reduced weight and power consumption and an improved control system to drive a mechanical exoskeleton fitted to a patient's disabled arm in order to restore some functional use of the hand and arm.

IRM-22 -- A means of tracking the eye movements of hemoplegic patients as they view test material in order to determine causes of visual difficulty which incapacitate otherwise functional patients and in order to permit formulation of rehabilitation procedures designed to restore hemoplegic patients with scanning difficulties to more normal and useful lives.

IRM-23 -- A simple, reliable alarm to indicate respirator failure so that frequent surveillance by nurses would not be required on patients who need respirator assistance for long periods of time.

LSU-1 -- An improved respirator design which will allow a polio victim to sit up in a wheel chair while the respirator is operating.

MCV-2 -- A high-intensity, soft X-ray source to permit visualization of soft tissue in the body for diagnostic purposes with direct applicaiton to mammography to detect tumors of the female breast.

NCI-1 -- Techniques for reducing noise levels in prefabricated, modular, laminar flow, sterile rooms which have been developed for patients undergoing cancer chemotherapy.

NCI-2 -- A transducer for continuous monitoring of lactate and pyruvate concentrations in blood in order to rapidly detect the onset of shock in patients undergoing treatment for leukemia.

NCI-3 -- A noninvasive, reliable and comfortable transducer for continous monitoring of blood pressure in order to rapidly detect the onset of shock in patients undergoing treatment for leukemia.

NCI-4 -- A method of rapid cooling at a uniform rate from room temperature to -50°C of a volume of white blood cells in order to store them for subsequent use in the treatment of leukemia.

NCI-6 -- A nondestructive technique for fractionating white cells taken from human blood into categories which can be physically distinguished in order to facilitate basic studies of leukemia and eventually other forms of cancer.

NCI-7 -- A method for rapid heating at a uniform rate from -50°C to room temperature of a volume of frozen,stored, white blood cells in order to replace white cells in leukemia patients who have an insufficient supply of white cells as a result of treatment for leukemia.

Table 5. (Cont.)

NCSU-9 -- Recent developments in the basic theory of nearly periodic and nearly stationary stochastic processes for advancing studies of the human electroencephalogram as a tool for diagnosis of specific and localized brain disorders.

TU-1 -- A pressure transducer for measuring shock waves in the brain and for use as a basic research tool in understanding brain damage occurring in automobile accidents, falls, and other accidents.

TU-2 -- A transducer for measuring respiratory rates in children at play in a hospital clinic for diagnosis of respiratory disease.

TU-3 -- A method for determining the frequency spectrum of breathing sounds on the chest of children in a hospital clinic for diagnosis of respiratory disease.

TU-5 -- A transducer for measuring the change in dilation of a small section of the heart wall during a complete pumping cycle and generating an artificial heart control system input signal.

TU-6 -- An on-line, real time transducer for monitoring blood gases (O_2, CO_2, pH) in patients during the critical phase following surgery.

UNC-50 -- A small pressure transducer for use in rehabilitation of patients with injured hands is needed to permit quantitative evaluation of patient function plus his response to therapeutic procedures.

UNC-55 -- A method of automatically detecting and recording position vs. time for infants crawling freely in a closed room for basic psychological studies.

WF-29 -- A rapid response (30 seconds) electrode to measure hydrogen ion concentration and carbon dioxide partial pressure in the blood for use in a research program to determine the effect of carbon dioxide on the response of certain areas of the brain.

WF-53 -- A means of obtaining the velocity spectrum of blood flowing in veins and arteries thus permitting the accumulation of more accurate information on blood flow which could be applied to the improvement of cardiovascular system models.

Table 5. (Cont.)

WF-56 -- An improved fluid pressure calibration system to be used in blood pressure transducer calibration.

WF-61 -- An accurate transducer for measuring blood vessel volume elasticity (preferably *in vivo*) in order to: (1) improve mathematical models used in studies of cardiovascular function and (2) evaluation of total cardiovascular function in human patients.

WF-62 -- A small, thin pressure transducer to measure the pressures exerted on tissue by support-type hosiery so that the effects of such hosiery on the vascular circulation in the legs can be determined.

WF-64 -- Techniques for increasing input dynamic range, linearity and frequency response in volume plethysmography transducers so that subtle changes in blood volume waveforms resulting from abnormalities in the human circulatory system can be detected.

WF-67 -- A filter to separate data occurring at nominal heart rates (80 per minute) from data occurring at nominal respiration rates (10 per minute) in plethysmographic data. Volume changes associated with heart action and respiration action are superimposed in plethysmographic data rendering interpretation of the data extremely difficult.

WF-72-- Circuitry which could be used to control a tilt bed in response to patient blood pressure variations so that tilting of the bed would result in reduction of blood pressure variations in the patient.

WF-73 -- A means to determine the local site of bleeding in the intestine so that corrective treatment and/or surgery can be accurately applied to the bleeding site.

WF-74 -- Improved methods of measuring amino acid concentration in the brain to enhance studies of the "blood-brain" barrier which at present is not understood.

WF-77 -- A method for measuring heat loss from the surface of the skin as a result of evaporation of perspiration to permit assessment of blood flow in human peripheries and correlation with arterial disease.

WF-79 -- Methods of computer analysis of chromosome data so as to permit rapid detection, for mass screening purposes, of mongolism in fetuses sufficiently early to permit therapeutic abortion.

Table 5. (Cont.)

WF-80 -- A reliable, self-powered, simple-to-operate and inexpensive infusion pump for continuous 24-hour operation in the treatment of cancer patients in the home environment.

WF-81 -- A means of determining whether blood flow in a tube is laminar or turbulent so that the effectiveness of mixers at the sampling and injection site in basic indicator concentration methods can be assessed.

WF-82 -- A means of preventing "washout" of dye from tip of a dye injector in indicator concentraiton methods of studying blood flow, so as to eliminate the error contribution made by dye entering the flowing blood after dye injection has theoretically ceased.

WF-83 -- FORTRAN - compatible computer programs for the storage and retrieval of infrared spectrographic data on selected chemical compounds to permit the rapid identificaiton of unknown compounds from infrared spectrographic data.

WF-86 -- A means of reducing anxiety in patients during therapy by noncontact stimulation so that hyperventilation and consequent loss of consciousness can be prevented, thus effecting a significant savings in time to the patient and the psychiatrist.

NIMH-1 -- A transducer to detect the onset of urination by geriatric patients.

MISC-4 -- A portable self-powered freezing unit for storing smallpox vaccine in remote, tropical regions.

Table 6. Impact Areas

1. DETECTION AND PREVENTION OF COMMUNICABLE DISEASE

None

2. IMPROVED INSTRUMENTATION AND TECHNIQUES FOR CLINICAL DIAGNOSIS, MULTIPHASIC HEALTH SCREENING

RTI/BH-1	Respiratory Measurement During Exercise
BH-2	Respiratory Gas Analysis During Exercise
BH-3	Blood Pressure During Exercise
BH-4	Blood Flow During Exercise
BH-5	ECG During Exercise
*DU-31	Catheter-Mounted Pressure Transducer
*DU-47	Urethral Pressure Transducer
*DU-61	Improved Resolution for X-ray Fluoroscopic Images
*MCV-2	High Intensity Soft X-ray Sources
*NCSU-9	Analysis Techniques for Physiological Data
*TU-2	Respiratory Rate Measurement
*TU-3	A Lung Sound Detection
*WF-61	An Improved Method of Determining Volume Elasticity of Blood Vessels
WF-67	A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data
*WF-73	Determination of the Site of Bleeding in the Intestine
WF-83	Identification of Infrared Spectra Using Computer Techniques
BH-6	Exercise Capacity and Standardization in Human Stress Testing

3. PROVISION OF IMPROVED REHABILITATION MEDICINE AND TECHNIQUES

*RTI/DU-58	Urine Disposal System
IRM-2	A Body Power Energy Storage System
IRM-14	Motion Force Amplifier
IRM-22	A Means of Tracking Eye Movements While Viewing Printed Matter, Geometric Forms, and Pictures

Table 6. (Cont.)

RTI/NIMH-1	Urination Detection
IRM-24	Waste Management Technique
LSU-1	Improved Artificial Respirators
UNC-50	General Purpose, Indicating, Pressure Sensitive Muscle Trainer

4. DEVELOPMENT AND EVALUATION OF ARTIFICIAL ORGANS

RTI/TU-5	Measurement of Change in Heart Wall Dimensions

5. DEVELOPMENT AND EVALUATION OF ORGAN ASSIST DEVICES

RTI/IRM-5	An Improved Flexible Lead Wire for Implantable Devices

6. DETECTION AND TREATMENT OF MENTAL HEALTH PROBLEMS

*RTI/UNC-55	Noncontacting Method for Human Infant Position Determination
WF-79	Computer Processing of Chromosome Data
WF-86	Reduction of Anxiety by Noncontacting Stimulation

7. DETECTION AND TREATMENT OF HEART DISEASE

*RTI/DU-31	Catheter-Mounted Pressure Transducer
*DU-61	Improved Resolution for X-ray Fluoroscopic Images
*WF-53	Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins
*WF-56	An Improved Fluid Pressure Calibration System
*WF-61	An Improved Method of Determining Volume Elasticity of Blood Vessels
WF-62	An Extremely Thin Pressure Transducer to Measure the Pressure Exerted on Tissue by Support-Type Hosiery
WF-64	Improved Method of Making Volume Plethysmographic Measurements Related to Volume Changes in Tissue Caused by Influx and Efflux of Blood During the Cardiac Cycle
WF-77	A Means of Measuring Evaporative Heat Loss from the Skin
CP-3	Automated Measurement from Coronary Angiograms

Table 6. (Cont.)

8.	DETECTION AND TREATMENT OF CANCER	
	*RTI/MCV-2	High Intensity Soft X-ray Sources
	NCI-1	Noise Reduction in Laminar Flow Rooms
	NCI-2	Lactate/Pyruvate Measurement in Blood
	NCI-3	Blood Pressure Measurement
	NCI-4	Controlled Rate of Freezing a Liquid
	*NCI-6	Separation of White Cells
	NCI-7	Method of Fast Warming of a Frozen Liquid
	WF-80	A Miniature Infusion Pump
9.	ASSESSMENT AND IMPROVEMENT OF ECOLOGICAL SYSTEMS	
	None	
10.	REDUCTION OF HEALTH CARE COSTS	
	RTI/IRM-23	A Respiration Alarm
	WF-72	Automatic Control System for a Tilt Bed
	CP-4	Real Time Data Acquisition During Batch Processing
11.	DEVELOPMENT AND PROVISION OF REMOTE HEALTH CARE SERVICES	
	RTI/CP-1	Data Compression Techniques: Software
	MISC-4	Freezing Unit for Smallpox Vaccine
12.	PROVISION OF MORE/BETTER MEDICAL PERSONNEL	
	None	
13.	DETECTION AND TREATMENT OF KIDNEY DISEASE	
	*RTI/DU-47	Urethral Pressure Transducer
	*DU-48	Urine Flowmeter
	*DU-58	Urine Disposal System
14.	REDUCTION OF INFANT MORTALITY	
	RTI/DU-66	Tissue Oxygen Monitoring During Childbirth
15.	DETECTION AND TREATMENT OF RESPIRATORY DISEASE	
	*RTI/TU-2	Respiratory Rate Measurement
	*TU-3	A Lung Sound Detection

Table 6. (Cont.)

16. IMPROVEMENT OF SURGICAL AND RELATED TECHNIQUES

RTI/DU-59	Temperature Measurement on a Small Brain Probe
*WF-73	Determination of the Site of Bleeding in the Intestine
TU-6	Measurement of pCO_2, pO_2, pH in Blood

17. DENTAL AND ORAL

None

18. BASIC RESEARCH

RTI/DU-63	Measurement of Single Nerve Cell Activity
DU-65	Strain Measurements in Ligaments
DU-67	Synthetic Resins for Cell Separation in Immunological Research
DU-68	Grooves in Glass for Cell Growing
*NCI-6	Separation of White Cells
*NCSU-9	Analysis Techniques for Physiological Data
TU-1	Shock Wave Measurement
UNC-55	Noncontacting Method for Human Infant Position Determination
WF-29	An Electrode for Measuring Hydrogen Ion Concentration and CO_2 Partial Pressure in the Blood is Needed
*WF-53	Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins
*WF-56	An Improved Fluid Pressure Calibration System
*WF-61	An Improved Method of Determining Volume Elasticity of Blood Vessels
WF-74	Assay of Amino Acids in the Brain
WF-81	A Means of Detecting Turbulence in Blood Flowing in a Tube
WF-82	Prevention of Tip Washout in Dye Injection Techniques

* Indicates multiple impact area.

4.0 COMPUTER INFORMATION SEARCHES

This section contains a brief summary of computer information search activities of the RTI BATeam during the reporting period. Also reported here are preliminary investigations of the effects of search strategy on completeness of searches and an initial assessment of how RECON searches can supplement searches performed at NCSTRC.

4.1 Summary of Computer Information Searches at North Carolina Science and Technology Research Center (NCSTRC)

During the reporting period the RTI BATeam initiated 41 computer information searches at NCSTRC and evaluations of 28 search bibliographies were completed. The fact that the number of searches initiated exceeds the number evaluated reflects the increased emphasis on computer searching during that period.

Of the 28 searches evaluated, nine included citations judged relevant to solutions to problems by the team and by the problem originator. Two computer searches at NCSTRC resulted in transfers. Two searches were judged relevant but were not evaluated by the problem originator; the problems were closed. The remaining 17 evaluated were judged by the team and the problem originator as not relevant to the solution of problems. Of these 17, six were felt to be incomplete. The team has had indications in previous searches that the searches were incomplete and as a result initiated the comparative study of the importance of search strategy which is reported in the following section.

4.2 Dependence of Computer Search Results Upon Search Strategy

In December of 1968, a computer search was initiated on problem WF-53, "Means of Obtaining the Velocity Spectrum of Blood Flowing in Veins and Arteries." The problem was explained to an applications engineer at NCSTRC and a search strategy was formulated. Since a large number of citations was expected, particular care was exercised to exclude documents related to doppler effects at other than ultrasonic frequencies. The search was run; the result was no citations. Two more search strategies were subsequently formulated, and the searches were rerun. The final result was a search bibliography with 39 citations. No information was obtained from the search which could be directly applied to the problems in spite of the fact that the search had been run three times with three different search strategies. In addition, the concensus of opinion among BATeam members and the applications engineer at NCSTRC was that there should be a significant amount of information in the system on this subject.

More recently, the Western Research Application Center (WESRAC) and the Aerospace Research Applications Center (ARAC) were asked to run a search on

the same problem. The same description of the problem was given to both WESRAC and ARAC as that given to NCSTRC originally. WESRAC and ARAC were told, however, that NCSTRC had encountered difficulty in obtaining relevant information. In addition, the exclusion of doppler signals other than ultrasonic was omitted.

The WESRAC search contained 220 citations. The ARAC search contained 302 citations. Each of the three searches were then examined. Every document which was considered pertinent to the subject was selected. This selection process does not imply that the documents were potential solutions to the problem or, for that matter, relevant to the problem. Rather, these documents represent the types of documents one would expect to obtain when searching this subject area. This, of course, is a subjective judgment.

The selected documents are compared in Table 7. The influence of the knowledge that NCSTRC had experienced difficulty in their search upon the search strategies used at ARAC and WESRAC is shown in the relative number of citations obtained by the three RDC's. It is again stressed that these data do not represent nor are they intended to represent a comparison of RDC performance. Two features of the data in the table are felt to be significant. These are:

(1) Only one document is common to the outputs of the three searches; and,

(2) Of the 25 pertinent documents identified in all three searches, 20 were identified by only one of the searches.

This exercise illustrates clearly the sensitivity of the search output to the manner in which the search strategy is written. It also indicates the difficulty of obtaining all available information in the aerospace information bank relevant to a specific problem. It can be inferred from this exercise that there are few circumstances under which one can be certain he has obtained <u>all</u> the pertinent information on a given topic.

4.3 Experience with RECON Search System

The RECON search system has been developed for NASA to allow real-time-on-line searching of the aerospace information bank. Search strategies are designed and modified by an individual with the assistance of the system. As the individual constructs a search strategy, he is shown on a visual display the number and type of citations which are being assessed and he is shown similar search terms which can be used to modify the search strategy in order to more nearly obtain the results expected and desired. Another feature of RECON is that access to "X" documents (limited distribution documents) can be obtained.

The RECON system located at NASA Headquarters in Washington, D. C. was used to perform a search on problem DU-48, "Urine Flowmeter." The search was performed by a member of the BATeam, Dr. F. T. Wooten; this was his first

Table 7. Selected Citations from Three Searches on Problem WF-53.

ARAC	WESRAC	NCSTRC
N68-10458	N68-10458	N68-10458
N64-14422	N64-14422	
A64-22956	A64-22956	
A66-80604	A66-80604	
A66-80620	A66-80620	
A64-24539	A66-81377	A68-34858
A66-35024	A67-33161	N62-10490
A66-40896	A68-34466	N68-17959
A68-34028	N65-17349	N68-31985
A69-10298	N66-27800	
A69-31298	N67-25974	
A69-26546	N67-31198	
N68-27554	N68-24276	

encounter with RECON. The results of the search were 39 citations with 11 of the citations being "X" documents. A search performed at NCSTRC yielded 20 citations with, of course, no "X" documents. Fourteen citations were common to both the RECON and NCSTRC search bibliographies. These data, although not necessarily significant, indicate the potential for greatly increasing the number of documents identified as possible relevant to the solution of problems by supplementing RDC searches with RECON searches.

5.0 SPECIAL TASKS

During the reporting period the RTI BATeam initiated three studies aimed at enhancing the overall effectiveness of the BATeam program. All three of these studies or special tasks are continuing as of March 1970. The approach taken, conclusions to date, and future plans for each of these tasks are summarized in this section. The three tasks reported here are:

Investigation of the Potential for Transferring NASA-generated Computer Software to Applications in Medicine.

Investigation into Possibility of Establishing BATeam-Industry Interface

Investigation of BATeam Program Management Techniques.

5.1 Investigation of the Potential for Transferring NASA-Generated Computer Software to Applications in Medicine

5.1.1 Introduction

Reported here are the results of an investigation into the subject of applications of NASA-generated computer software in medicine. The BATeam has attempted to answer the following questions:

What level of software is most effectively or most usefully transferred?

To what types of biomedical users can this software most effectively be transferred?

How do we best match the biomedical user's problem with the NASA-generated software answer?

The team had originally intended to try to characterize NASA-generated software as to its potential usefulness in medicine, and also to characterize medical needs for computer software. Then, the above questions would be answered by cross-correlating the two sets of characterizations described. Almost immediately it became clear that this could not be done. Instead, it is believed that the discrete problem-oriented method already used in the BATeam program is appropriate for computer software transfers: first define the medical computation problem, and then see if an answer exists in NASA-generated software.

5.1.2 Methods of Investigation, Sources of Data, Opinions

The following sections are discussions of the methods of investigation and the sources of data used in this software-related study.

5.1.2.1 Consultants

Two members of the Biomedical Engineering Division of the School of Engineering at Duke University, Dr. Theo Pilkington, Chairman, and Dr. F. L. Thurstone, Associate Professor, have devoted approximately one day per week each to this investigation. They were to identify several software transfers in a short time, concentrating their efforts in areas where programming requirements were relatively simple. They were also to identify several major areas of medical software needs, by the types of software available within NASA.

5.1.2.2 Definition of Possible Biomedical Software User Community

Listed below are some of the people or groups with whom the team has talked in trying to characterize possible biomedical users of NASA software.

Other BATeams -- Software transfer experiences of the past were discussed with members of the BATeams at both Southwest Research Institute and Midwest Research Institute.

BATeam Consultants -- Software transfer possibilities have been discussed at length with Dr. E. A. Johnson, our regular BATeam consultant at Duke University Medical Center. The subject has also been discussed with Dr. George Malindzak, Jr., the BATeam consultant at Bowman Gray School of Medicine of Wake Forest University.

Duke University Computer Users -- The team has assumed that Duke University Medical Center is typical of most medical research centers and has concentrated upon Duke University in this investigation because of its geographical convenience and because of the number of people at Duke who are experts in all aspects of computer use. A partial list of the Duke staff with whom this has been discussed includes:

Dr. R. Ames Schroeder, Director, Duke University Computer Center;

Dr. Thomas Gallie, Professor of Biomathematics and Mathematics;

Dr. E. Harvey Estes, Chairman of Department of Community Health Sciences and Administrative Head of Digital Computation of the Duke University Medical School;

Dr. C. Frank Starmer, Assistant Professor, Department of Medicine and Myocardial Infarction Research Unit;

Dr. W. E. Hammond, Assistant Professor, Department of Community Health Sciences and Division of Bioengineering;

Dr. Dietolf Ramm, Associate, Department of Community Health Sciences.

Science Information Exchange (SIE) of the Smithsonian Institute -- The Smithsonian Institute provides a search of abstracts of research sponsored by federal agencies, and state, university, private granting, and commercial organizations. To assist the team in defining medical users of software, SIE performed a search of current grant abstracts to identify projects involving the development and application of computer software in general.

RTI In-House Computer Users -- The team has had a number of discussions with various RTI personnel involved in computer applications, including Mr. Bob Browning, Director of the RTI Computer Center.

5.1.2.3. Access to Software Information within NASA

Listed below are some of the individuals who have been contacted in identifying means of finding NASA-generated software to solve a specific biomedical problem.

Technology Utilization Offices at NASA Field Centers -- The team has contacted a number of TUO's to understand how they now handle software problems and to determine whether each NASA center has a list of most of the computer programs available at that center.

NASA Program Library -- Mr. Eugene Brock at Manned Spacecraft Center (MSC) in Houston is in charge of a Program Sharing Library which is part of the NASA resources sharing program. The team has contacted Mr. Brock about software transfer in general, and has applied for membership in the Program Sharing Library so that the RTI BATeam can obtain complete information on the types of programs which can be found in NASA. Also, literature searches were run on the two subjects, Data Compression and Structural Analysis, to assess this means of finding NASA software information.

Computer Software Management and Information Center (COSMIC) -- COSMIC has information on locating other programs in addition to the approximately 2000 computer programs which they have on file. We have discussed software transfer in general and COSMIC's resources in particular with Mr. Harry B. Rowell, Director, COSMIC.

Regional Dissemination Centers (RDC) -- Software transfer and appropriate search strategies for software transfer problems have been extensively discussed with Mr. T. R. Potter of NCSTRC.

NASA Flash Index -- The Flash Index should be included in any list of means of accessing information within NASA.

5.1.3 Levels of Software Transfer

The term "software" has been used in a very loose and general sense to this point. Instead of a tighter definition of software, four different

levels of software transfer, to be referred to as Type I transfers, Type II transfers, etc., will be defined. These levels are outlined below:

Type I: User's Access to a Program at a NASA Field Center

The Type I transfer applies to a case in which the biomedical user is unable to implement a needed program at his facility, due to prohibitive program size, specialized Input/Output (I/O) facilities, or other reasons. NASTRAN generally would qualify as such a program.

Type II: Transfer of a Complete NASA Program for Use at the Biomedical User's Installation

A Type II transfer applies to the case in which an existing NASA program is transferred virtually intact, or with minor modifications, for use at the biomedical user's own installation.

Type III: Use of Portions of One or More Programs

In many cases, one may be able to develop a needed program by employing portions (probably subroutines) of one or more existing programs. Thus, a biomedical application of a NASA subroutine is a Type III transfer.

Type IV: Algorithms and Precoding Information

In many cases the biomedical user's computer facilities will be so different from the NASA computer facilities for which the program was designed that the biomedical user will find it more economical to rewrite the program completely. The algorithms in the original program, the "how to do it" general logical flow of the program, could still be extremely useful in writing a similar program for the biomedical user's installation. Thus, a Type IV transfer is a transfer of NASA technology but not of a packaged program.

5.1.4 Software Transfer Barriers

The following paragraphs outline the conditions which must be satisfied and the major barriers to the four types of software transfers defined in the preceding section.

Type I Transfer -- Barriers to Type I software transfers are primarily operational in nature. One of the major problems likely to be encountered is scheduling computer time at the NASA center to coincide with the problem originators' visits to the center which of course will be dependent upon the time which the center personnel can devote to working with the problem originator. These operational problems coupled with the strong tendency of medical personnel to perform their work at their own facility indicates that relatively few Type I transfers will be accomplished.

Type II Transfer -- A Type II transfer is the least likely of all in the view of many individuals who have been contacted in this study. Computer centers are all different and the debugging associated with direct transfer is very difficult, even in those cases in which portions of the original program were written in a machine-independent lower level language such as MAP or FAP.

The biomedical user must either be a competent programmer or have access to one. This type of transfer is probably the easiest to document and the most unlikely to achieve.

Type III Transfer -- A Type III transfer is more probable than a Type II, but many of the subroutines that might be considered are already available to the biomedical community from sources as the IBM Scientific Subroutine Package and the BMD and BNDX program series of the UCLA Health Sciences Computing Facility. In documenting a Type III transfer, it might be difficult to identify the uniqueness in the NASA subroutine transferred.

Type IV Transfer -- The Type IV transfer is probably the easiest to achieve in general. The form of the information actually transferred might be as substantial as a document giving program flow charts, or as intangible as a series of telephone conversations between the biomedical user and the group who produced the NASA program. This information transfer can be very valuable to the biomedical user and constitutes a NASA technology transfer, but may be somewhat difficult to document.

The above discussion implies that the biomedical user must know programming or have access to programmers for all types of transfers except Type I.

5.1.5 Conclusions and Recommendations

It is concluded that a good potential exists for Type IV transfers, and that any general approach to biomedical software transfers should aim principally at Type IV transfers, handling other transfer types on an ad hoc basis as they arise. The nature of the information being transferred in a Type IV transfer has to be clearly understood by all parties concerned with assessing the value of the transfer.

This proposed biomedical software transfer process should fit into the existing BATeam program with only those few changes indicated in the following paragraphs. Software transfer to biomedicine does not seem to warrant the establishment of a separate transfer mechanism.

Problem Selection -- As already indicated the problem originator must have or have access to programming capability if software transfers are to be accomplished. The BATeam should aim for Type IV transfers in general but should stay flexible enough to handle other types of transfers as well.

Problem Statements -- The problem originator should be used more heavily in the actual problem statement preparation if possible because he will probably know more than the team member about what programming information is needed. This is a reversal of the situation in the conventional BATeam program, and the extra knowledge of the problem originator in the software problems must be utilized to insure that the problem statement contains all necessary information.

Each BATeam should designate one of its members to act as the team's expert on software problem statements. He should read each software statement to be sure the right information was supplied.

A software-related problem statement is designed to ask NASA center personnel whether they have done a given type of programming or not. Unlike the ordinary BATeam statements, the software problem statement should not attempt to solicit an inventive suggestion from the center personnel. Only past accomplishments are of interest for the Type IV software transfer.

Since a software problem statement is only trying to elicit a "yes" or a "no" based on past history, and is not seeking the single inventive or creative suggestion which is so important in the regular BATeam program, circulation of the statement at NASA Field Centers should be highly selective instead of the broad exposure that is sought in the case of other problem statements. Most (but not all) of the NASA Field Centers have a list of all computer programs in use at that center. It will be very important to get problem statements to the location of those lists. In addition to the TUO channels, it will be very important to send copies of problem statements to the Program Sharing Library and to COSMIC.

5.1.6 Categories of NASA-Generated Computer Software Having Potential Application in Medicine

The following tentative categorization of NASA software is based exclusively upon programs listed in COSMIC's publications. Since the team is advocating the discrete problem-oriented approach to software transfer, we do not plan to expend appreciably further efforts to improve or refine the following categories:

Network Analysis -- A wide variety of programs are available in this area. Such programs are of a general nature and are applicable to both A.C. and D.C. networks with active and passive components. The user is free to specify any given circuit configuration within the constraints of the program.

The programs fall into the following categories:

(1) Computation of node voltages and branch currents.
(2) Frequency response analysis.
(3) Transient analysis.
(4) Performance analysis.

Fluid Mechanics -- These programs are primarily concerned with fluid flow (both compressible and incompressible) in mechanical systems. The main classification of these programs are:

(1) Prediction of flow distribution in piping systems.
(2) Orifice sizing to achieve desired steady state flow rates.
(3) Heat exchanger analysis.
(4) Interface mass transfer.

Structural Analysis -- There are several programs available in this area, and they can be categorized as follows:

(1) Analysis of shells of revolution (e.g.,cylinders and cones) to determine bending under loading (or pressurization) and to determine strength.
(2) Analysis of loading of beams, columns, flat plates, etc.
(3) Vibration analysis.
(4) Stress analysis for various mechanical configurations under loading conditions.

There are at least two programs of sufficient flexibility to allow the user to select a variety of elements which can be interconnected to form a desired composite structure. The programs then compute equilibrium, stress at various points, deflections at various points, etc.

Signal Processing -- There are very few programs of this nature. Typical are programs for the following:

(1) Digital filtering.
(2) Data conditioning.
(3) Digital image processing.

System Optimization -- There are two general classes of optimization programs available.

(1) Optimization programs of a general nature (e.g., maximizing or minimizing a function subject to a number of constraints).
(2) Optimization programs developed for a specific purpose which possibly have broader application. Examples of this type are:

    (a) Minimization of drag on an arbitrary platform.
    (b) Electrical transformer design optimization.
    (c) Optimal trajectory transfer for minimal propellant consumption.
    (d) Optimum inventory size based upon time varying description of the behavior of the inventory level during withdrawal and replenishing processes.

5.1.7 Summary of Current Activities in Software Transfer

A large part of the team's efforts to this point has been expended in giving form to the original somewhat amorphous concept of software transfer. With this model, the team is now processing various computer-related biomedical problems. In effect, our investigation has been completed and we are in the operational phase, processing the first set of software problems.

Because of the size of the NASA structural program, NASTRAN, it would be

a Type I transfer, at least initially. The team has discussed NASTRAN's capabilities with some of the contacts made in this investigation and has two different possible leads to future NASTRAN users.

Dr. John Justice of the University of Wisconsin has expressed interest in NASTRAN for his research on vibratory properties of long bones. The team is presently looking into procedures to follow in this case, but NASTRAN has not yet been released to the public. Also the Midwest Research Institute BATeam is already working with Dr. John Cameron, University of Wisconsin, who is the principal investigator for the grant which is supporting Dr. Justice's research. These are merely details however which should be easy enough to work out.

Dr. Theo C. Pilkington, Duke University, has agreed to evaluate NASTRAN's potential. Dr. Pilkington is acquainted with several people doing biometrics and human structural analysis research at different locations in the country and can advise the team of the most promising NASTRAN users.

Problems CP-1 through CP-4 which were accepted during the reporting period have resulted directly from this investigation of the potential for applying NASA software in medicine. The problem code CP indicates simply that the problems are computer-related problems. Additionally, the team is now in the process of defining five other computer-related problems which are not reported here. It is the concensus of the BATeam that the probability of achieving transfers for these problems is considerably higher than is the case with the "average" problem investigated by the team. This statement, of course, remains to be validated. It is expected that an accurate and valid assessment of the success to be expected in Type IV transfers can be made within six months.

5.2 Investigation into Possibility of Establishment of BATeam-Industry Interface

To evaluate the feasibility of BATeam participation in the transfer of NASA technology into private industry, RTI has completed a preliminary survey of the biomedical instrumentation manufactures and initiated technical discussions with university and industrial management staffs.

To provide further insight into the problems of industrial product development and marketing of medical equipment, the BATeam visited the Institute of Science and Technology (IST) at the University of Michigan. The Industrial Development Division of IST has developed several seminars on industrial problems in medical instrumentation and has sponsored a Ph.D. dissertation on "Constraints to the Development and Marketing of Medical Electronic Equipment." [Ref.2]

In conversations with Mr. Don Smith, Assistant Director, Industrial Development Division; Mr. Ernie Sellers, Biomedical Research Engineering; Professor Glen Edmunston, Director, Biomedical Engineering Program; and Professor Al Swinyard, Associate Dean, School of Business Administration; it was possible to highlight several significant opinions.

There is a general concensus among those interviewed at Michigan that the biomedical marketing problem is as difficult as, if not more so than, any other field of industrial marketing. The marketing difficulties are related to several factors:

(1) The instrumentation requirements for a given area of medical specialization cannot be characterized by an interview technique which samples a representative number of the medical population.

(2) New product acceptance is best demonstrated by an experienced physician's clinical reports of its successful application.

(3) Only well-known and established medical instrumentation companies can attract a physician's attention to a new product.

(4) Sales personnel from established companies must have comprehensive engineering knowledge of the product and its potential medical application.

(5) Small manufacturers or newly established medical engineering companies are better advised to sell their innovations to established medical instrumentation companies for their subsequent marketing.

(6) The larger more successful companies market their product regionally, not nationally, and spend one to two years in product engineering prior to marketing. They generally anticipate recovering the cost of the product engineering effort in the first two to three years after it is placed on the market.

The conclusions of the Michigan study are as follows:

First, an organization having the confidence of both doctors and industry is needed to provide a momentum that will improve present and potential markets for medical electronic equipment.

Second, the doctors which appear to be most interested in present and potential applications of electronics to medicine are either medical researchers or clinicians involved in specific fields such as cardiology, neurology, radiology, or anesthesiology.

Third, national symposiums have not been an effective communications media between physicians and industry because of the extremely diverse interests of engineers, the medical profession, and the manufacturing and marketing organizations.

Fourth, and perhaps most important, is that the limitations curtailing medical electronics development is not in scientific technology, but more probably in effective marketing techniques and improved medical engineering communications.

To provide an industrial viewpoint on the potential applications of aerospace technology, the BATeam met with the bioengineering staff of the Becton-Dickinson Research Center in Raleigh, North Carolina. Discussions with Mr. Matt Petrovick and Mr. V. A. Pace were considered significant in that Becton-Dickinson's research laboratory represents a broad spectrum of biomedical interests in approximately 37 different divisions of their company.

The Becton-Dickinson bioengineering staff conference suggested two possible avenues for technology transfers. One possibility would be to include Becton-Dickinson on an industrial distribution list for all BATeam transfers. It is anticipated that Becton-Dickinson (as well as other interested companies) would review the list of transfers for areas of

interest and potentially marketable products. A second avenue would be for Becton-Dickinson to identify problem areas currently undergoing product development. Becton-Dickinson would summarize their problem areas in anticipation of BATeam interest and their subsequent search through the aerospace technology. In either case, Becton-Dickinson would expect to respond in writing to confirm those problems in which the transfer data was used as a potential solution.

Finally, a listing of industrial manufacturers has been reviewed and those companies with electromechanical capabilities and interests have been identified as having a high probability for utilizing aerospace technology. The list includes 91 companies which have been separated into 18 specific instrumentation areas. The results of this review are attached to this report as Appendix E.

The information obtained to date do not indicate a workable mechanism for transferring the results of NASA's BATeam program to manufacturers of medical products. Possibly the next appropriate step is to obtain from industry additional facts on new medical product development and marketing. A management survey of a representative sampling of the compaines listed in Appendix E could be conducted in approximately three months. The results of such a survey would certainly indicate whether effort in this direction is warranted, if it did not, in fact, indicate possible mechanisms for technical transfer to industry in the important area of medical equipment.

5.3 Investigation of Biomedical Application Team Program Management Techniques

5.3.1 Introduction

Assuming that the BATeam develops its problem screening capabilities to the point that they are optimum and can no longer be improved, problems will still be accepted which cannot be solved. In the interest of continually increasing the team's efficiency in terms of cost-benefit ratios, some method of deciding when to terminate efforts to solve a problem is needed. Since the BATeam program is a fairly well defined process of information transfer and problem solving, a reasonable approach to developing the desired management tools would be to break the process up into well-defined types of activities and record the man-hours required to complete these activities for each problem investigated. Following the accumulation of a significant amount of data, it can be postualted that the average effort required to complete the various activities involved in accomplishing transfers could be used to make management decisions. That is, if the effort devoted to, for example, information searching in attempting to solve an active problem exceeds the average effort devoted to information searching in the case of transfers, then the active problem should be reviewed and possibly closed.

For approximately two years, the RTI team has recorded for all problems investigated the team effort devoted to six types of activity. A preliminary analysis of these data indicates that a model as simple as the one suggested in the preceding paragraph is not useful as a management tool. The results of this analysis are presented in Figure 3. The six types of activity used in recording team effort are given in the figure Average effort in man-hours is shown for each activity for all problems, closed problems, active problems, and problems resulting in transfers. Note in particular that the average efforts for closed problems and for transfers do not differ significantly in the early stages of the transfer process.

This result indicates that a more sophisticated and complete analysis of the data is required. At present, the BATeam with the assistance of RTI's Statistics Research Division is initiating such an analysis. The data format and the analysis technique is explained in the following paragraphs.

5.3.2 Analysis of Data

The total team-hours of effort is classified into various activity types. Earlier data give team-hours of effort for six types of activites. Data collected since November 1969 give team-hours of effort for 13 types of activities. These data are collected every week. For the

	Problem Identification	Information Search	Problem Abstract	Evaluation	Follow-up	Documentation
All Problems	6.5	10.8	3.7	7.1	7.6	3.8
Closed Problems	6.6	13.8	2.6	6.4	3.0	2.7
Active Problems	6.2	8.2	4.2	5.1	2.3	3.1
Problems Resulting In Transfers	6.7	11.9	6.0	9.0	8.4	4.0

Figure 3. Average number of man-hours of effort in different phases of activity (based on 2947.5 man-hours of effort).

purpose of this study, we shall only consider the data relating to completed projects and construct a table such as that in Figure 4 for the total hours spent in each activity for completed problem investigations.

The objective of the analysis is to use the data to devlop management tools to plan and control future activities.

The first step in the analysis will be to determine if (and how), on the basis of the distribution of total man-hours among the various activity types, the completed problems can be subdivided into groups (clusters) having similar such distributions. Since problems with the total man-hours classified into 13 categories of effort are available only for a short period as compared to problems with total man-hours classified into six categories, the 13-category data will be reduced to the six categories used earlier. For the purpose of this analysis, each completed project can be considered as a vector of six components. The six components of a vector can either be the actual hours of effort for each activity or the proportion of total time spent on each activity. The problems will then be grouped, using a cluster analysis procedure. For purposes of comparison, the problems will also be subjectively grouped on the basis of experience and other considerations. The result of this first step will be a number of categories into which problems may fall and which may be redefined as the analyses proceed and more experience is gained. Out of all these different types of groupings, we will select one type of grouping for further analysis.

The next step will be to define, for each problem category, a "norm" distribution of man-hours by activity type; each such distribution will specify the proportion of total anticipated man-hours to be spent in each activity type. Ultimately, in practice, a problem will be categorized a priori; as work proceeds on the problem, records will be kept of the man-hours spent in the various activity types. Should the appropriate norm value be exceeded, then a decision to stop work on the problem may be made. For some problems, however, the benefits of a solution may be sufficient to justify continuing on, even though a norm is exceeded. Consequently, as part of the overall procedure ultimately constructed, a decision rule which balances the benefit of a solution against the cost should be included. This is a feature to be put in at a fairly late stage in the process ; however, the activity presently to be undertaken is the cluster analysis described in the preceding paragraph.

Problem Code	Activity Type				Total Cumulative Hours
	A_1	A_2	. . .	A_M	
C_1	H_{11}	H_{12}	. . .	H_{1M}	$H_{1.}$
C_2	H_{21}	H_{22}	. . .	H_{2M}	$H_{2.}$
⋮	⋮	⋮		⋮	⋮
C_N	H_{N1}	H_{N2}	. . .	H_{NM}	$H_{N.}$

H_{ij} = No. of man-hours spent on activity j for problem i ;

H_i = Total no. of man-hours spent on problem i.

Figure 4. Biomedical Team-Hours of Effort

6.0 PRESENTATIONS AND VISITS TO NASA FIELD CENTERS

6.1 Presentations

During the reporting period, the RTI BATeam made four presentations on the NASA BATeam program. These four presentations are summarized in the following paragraphs.

On September 24, 1969, Dr. F. T. Wooten made a presentation on the Biomedical Application Team to the North Carolina Governor's Committee on Employment of the Handicapped. The meeting, in Greensboro, N. C., was attended by 325 business and professional leaders in the state. The team contacted Mr. James Wiggins, Technology Utilization Officer at Marshall Space Flight Center, who suggested that he send Mr. John Graham to demonstrate the sight switch discussed in NASA Tech Brief 65-10079. The presentation was well received.

On October 10, 1969, the team assisted Mr. James T. Richards, NASA, Technology Utilization Division, in a presentation to the North Carolina Rehabilitation Association Annual Meeting in Winston-Salem, North Carolina. The presentation, introduced by Congressman William Mizell, consisted of talks by Mr. Richards and Dr. Wooten, a movie prepared by NASA Headquarters, and a live demonstration of the sight switch and wheel chain by Mr. John Graham of Marshall Space Flight Center.

Mr. Ernest Harrison made a presentation entitled "The Biomedical Application Team Program - An Experiment in Active Technology Transfer" at an IEEE Section meeting in Portsmouth, Virginia, on November 18, 1969.

On March 19, 1970, Dr. Wooten made a presentation to the Instrumentation Division of Ames Research Center, Moffett Field, California.

6.2 Visits to NASA Field Centers

October 7, 1969: Marshall Space Flight Center -- Received overview of center's operations and talked to personnel in Astrionics Division and Non-Destructive Testing Area.

Team Members -- Dr. Wooten and Dr. Hayne

November 13, 1969: Marshall Space Flight Center -- Very productive discussions with Dr. Krause, Messrs. Andrew Elner and Jean Bond on WF-69. Transfer resulted.

Team Member -- Mr. Harrison

November 18, 1969: Langley Research Center -- Visited Langley to see the complex coordinator and determine its characteristics for future application to the BATeam program. Complex coordinator was eventually used by Dr. Wooten on AP-1 in Technology Application Team program. Discussed several recent responses on IRM-17 with Mr. John Samos.

Team Member -- Mr. Harrison

March 17, 1970: Jet Propulsion Laboratory -- Received overview of center's operations and discussed specific problems NCI-4 and NCI-3.

Team Member -- Dr. Wooten

March 18, 1970: Flight Research Center -- Received overview of center's operations. Discussed problem statements with Technology Review Board. Visited Biomedical Programs Office.

Team Member -- Dr. Wooten

March 19-20, 1970: Ames Research Center -- Received overview of center's operations. Discussed specific projects in Instrumentation Division.

Team Member -- Dr. Wooten

March 19, 1970: Electronics Research Center -- Mr. Fred Hillsman demonstrated the NASA oculometer. It clearly will solve problem IRM-22 but the major difficulty is getting a unit into the researcher's hands.

Team Member -- Mr. Harrison

March 31, 1970: Manned Spacecraft Center -- Visited center to pick-up impedance pneumograph hardware from Crew Systems Division for problem TU-2 problem originator. Received briefing on programs in Crew Systems Division. Also received overview of center from Mr. Jack Wheeler.

Team Member -- Dr. Wooten

6.3 Contacts with NASA Field Centers

One of the most critical aspects of a successful BATeam program concerns team interactions with NASA Field Centers. Much of the valuable information used by the teams does not appear in information searches and must be obtained through interaction with the centers. In order to optimize this interaction, the RTI BATeam analyzed the problems associated with the center contacts and proposed solutions to these problems.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations resulting from activities of the RTI Biomedical Application Team and from analyses of these activities for the period from 15 September 1969 to 14 March 1970 are presented in the following paragraphs.

Concerning the definition of technology transfers, it has been concluded that the BATeam program should adopt the rather stringent definition used in the Introduction to this report. This definition should be rigorously applied for two reasons. First, the rigorous application of this transfer definition will increase the team's emphasis on accomplishing more meaningful transfers of information and upon attempting transfers which involve new applications of aerospace technology and not simply the diffusion of technology. Second, and equally important, adopting this definition will facilitate clarifying the objective of this program to all individuals exposed to the program and in particular problem originators.

It is recommended that impacts as defined in this report be adopted as a legitimate and beneficial output of the BATeam program. This will allow a greater number of cases involving the beneficial transfer of information to the medical fields to be documented. Impacts, however, must not appear to team members or problem originators to be the objective of the Biomedical Application Team program.

Of the 8 significant transfers of 11 documented in this report, 5 involved direct contact between members of the BATeam and NASA Field Center personnel or NASA contractor personnel. Thus, it is clear that, due to the importance of being able to contact individuals involved in the space program, the teams must make every effort to insure that this line of communication remains open and effective. Specifically, it is recommended that the circulation of problem statements be made as selective as possible both from the standpoint of problem statements circulated and individuals to whom these problem statements are circulated. This means that circulated problem statements must be of high quality and should not duplicate problems defined in previously circulated statements. This also means that the teams should attempt to insure that, when a problem statement is circulated to an individual, the technology being sought is in fact related in some way to the experience or present activities of that individual. Additionally, it is recommended that Technology Utilization Office staff be increased so that the offices can more effectively handle the work load represented by the BATeam and TATeam problem statements. This increase in TUO staff could come from the Field Centers or to a certain extent be effected by BATeam and TATeam members. Finally, it is recommended that the teams integrate and coordinate plans for visiting Field Centers in order to optimize the value of these visits within the context of the entire BATeam program.

There are eleven NASA Field Centers staffed by over 10,000 engineers and scientists. A quick access to this technical expertise is a necessary part of an effective BATeam program. During the past four years the standard method for center contacts has been the circulation of problem statements to the individuals at the centers. This broad distribution of problem statements is effective on a small scale, but as the number of teams has rapidly increased, the Technology Utilization Officers (TUOs) at the centers have not had the manpower required to give careful consideration to each statement.

To solve this problem, it is clear that a more discrete problem statement distribution is required. In order to accomplish this goal, several tools can be used. First, the computer search provides some insight into center activities. Second, the NASA Program Digest provides an even better identification of NASA personnel.

The third approach has been evolving during this past year and promises to be the most effective. This approach involves team visits to the centers to gain a better understanding of center activities so that problem statements can be sent to only those centers with high probabilities of responding. It is clear, of course, that short visits to NASA Field Centers cannot make the team aware of the many specific projects of interest. However, the visits will make the teams aware of general program activities and then contacts can be directed by this awareness.

Thus, the team plans more direct contacts with the NASA Field Centers; therefore, to meet this goal visits have already been made to seven of the field centers. This effort is time consuming and must be carefully planned to optimize the time for the BATeam member as well as center personnel.

Another benefit of these visits is that they result in a greater awareness of the BATeam program among center personnel. For example, during the visit to Ames Research Center a seminar was held for the Instrumentation Division. The following day a NASA staff member visited the TUO and asked for copies of all problem statements. This generation of interest is precisely one of the results desired in center visits.

In addition to gaining a general program understanding, specific projects of interest often are presented during these visits. For example, active work on ultrasonics and oximetry at Ames Research Center had direct interest for researchers at Tulane School of Medicine. Another example occurred during the visit to Manned Spacecraft Center where it was learned that a joint project on blood pressure measurement was underway between NASA and U. S. Air Force. This has direct relevance to a problem at the National Cancer Institute.

This program of team visits to the centers could rapidly become ineffective if all teams did this simultaneously. Therefore, to reduce the requirement for travel, good reports of team visits must be circulated to all teams. To meet this need, trip reports on all visits have been circulated to all teams. It is hoped that all teams will reciprocate.

During this reporting period, the BATeam has continued to close or inactivate relatively large numbers of problems because of various conditions which should have caused these problems to be rejected at an early stage of the transfer process. Thus, it is concluded that although "good" problem selection criteria have been determined, they have not been effectively applied. It is easy to apply problem selection criteria at new user institutions. These criteria can be explained to consultants and problem originators and, as experience at Tulane University Medical School has shown, problem originators will themselves do a fairly effective job of screening problems. This indicates that the teams should establish new user institutions, in order to generally increase the probability of accomplishing transfers through the rigorous application of problem selection criteria.

The RTI team, as well as other BATeams, have recently determined impact areas for the problems which are being investigated by all teams. While this has indicated that the teams are in fact working on problems in important areas of the medical field, this has not involved the establishment of priorities for these different impact areas. It is recommended that medical impact areas for these problems be realistically correlated with present and future national medical objectives in order to allow the teams to direct their efforts to the most important technology problems in medicine. These national objectives and priorities could be established (1) by studying the allocation of funds within the Department of Health, Education, and Welfare, (2) by making use of the collective knowledge of a number of "knowledgeable individuals" in medicine, (3) through the application of the Delphi approach, or (4) by other techniques. It has been noted by a number of individuals including the Director of National Environmental Health Science Center, Dr. Cotin, that the medical problems faced by this nation in ten to twenty years will be entirely different from the problems faced today. Thus, when one considers the relatively long time required to effect the adoption of new technology in medicine, it is important that one look to the future in determining important target areas for technology transfer.

A recent study by the RTI team indicates that NASA-generated computer software can be transferred to applications in medicine, but it is likely that this transfer will not be direct; that is, program documentation and mathematical algorithms are more likely to be transferred than entire computer programs. Additionally, it has been concluded that this transfer of computer software should be approached with the same methodology that is presently used by the BATeams. It is important, however, that during the problem selection stage of the process some of the unusual aspects of computer software be kept in mind. Additionally, problem originators should have greater input in the preparation of problem statements.

The experience of the teams in computer information searching has indicated that many computer searches are incomplete and, further, that the results of computer searches are highly sensitive to search strategies. In discussions with Dr. W. Clingman, Clingman and Co., Dallas, Texas, who

is presently investigating the subject of computer search strategies, it has been learned that in the philosophy of Regional Dissemination Centers a key factor is relevance ratios and numbers of citations. It is recommended that, in computer searching for the BATeams, emphasis be placed upon completeness of the search as opposed to percentage of relevant documents.

Discussions between the BATeam and university and industry management experts have indicated that there are many constraints on the development and marketing of medical equipment. Marketing problems and not technological problems are the main barriers in introducing successful new medical instrumentation and equipment. A sound approach to the development of an effective interface between the BATeams and the medical industry has not been identified. It is recommended that additional information on the methods of new product development and marketing in this industry be obtained with the objective of identifying an effective BATeam-industry interface in mind.

Finally, it is recommended that the data which has been collected on the effort of the BATeams in different phases of the transfer process be analyzed in order to develop effective management techniques to be used at both the team and program levels. Preliminary analysis by the RTI team indicates that simple averaging techniques will not work. An analysis has been recommended in this report and is presently underway which should shed considerable light on how the teams devote their efforts to solving different types of problems. It is recommended that the data which has been collected by all three BATeams be analyzed in a similar manner in order to make the results of this program study more significant.

8.0 REFERENCES

1. "Biomedical Applications of NASA Science and Technology," Contract NSR-34-004-056 Final Report. N69-35786. Research Triangle Institute, Research Triangle Park, North Carolina, June 1969.

2. H. Ralph Jones, "Constraints to Development and Marketing of Medical Electronic Equipment," Dissertation, University of Michigan, Ann Arbor, Michigan.

APPENDIX A

A.1 Technology Transfer Reports

Transfer reports are included for the following 11 transfers accomplished during the period September 1969 to March 1970:

DU-45

46

IRM-3

7

8

20

NCSU-6

WF-31

33

69

VU-1

T R A N S F E R R E P O R T

RTI/DU-45

"Low Velocity Anemometry"

Dr. Steven Vogel, Duke University

Team Member - F. Thomas Wooten, Ph.D.

Problem Acquired - March 1969
Transfer Made - November 1969
Elapsed Time - 8 Months

Description of Problem

Dr. Vogel is interested in passive temperature control mechanisms in biology. In particular, he is concerned with the passive temperature control used by tree leaves. It is well known, in the field of biology, that leaves have a high infrared reflectance in order to maintain a relatively low temperature. It is also well known that the shape of a leaf varies from top to bottom of a tree. Dr. Vogel suspects that this shape variation is related to a passive temperature control mechanism.

In order to check his hypothesis, he is measuring heat dissipation of various shapes of sheet metal. Because heat dissipation is a function of ambient wind velocity, he makes his measurements in a low-speed wind tunnel. His technological difficulty arises in measuring wind velocities that are less than 2 mph. Dr. Vogel would like information on low-speed anemometers.

Description of Solution

Computer Search No. 1609, "Low Velocity Anemometry," was performed by the Science and Technology Research Center. This search disclosed 17 articles of interest to the problem originator.

The results of the search confirmed the researcher's opinion that the best way to measure the low velocities of interest was using hot wire anemometers which were discussed in detail in the 17 articles of interest. Using this information the researcher designed and built a low velocity anemometer which was utilized in his research.

Successful Searching Method

Computer search by Science and Technology Research Center.

Benefits to be Derived from Transfer

This transfer has enabled the researcher to conduct his studies on biological passive temperature control mechanisms. These studies have more than academic interest because of the many ways that man utilizes passive temperature control mechanisms. The results of this research will add to the growing bank of knowledge in this field.

T R A N S F E R R E P O R T

RTI/DU-46

"Electrode Material for Pacemakers"

Dr. James J. Morris, Duke University Medical Center

Team Member - F. Thomas Wooten, Ph.D.

Problem Acquired - March 1969
Transfer Made - September 1969
Elapsed Time - 6 Months

Description of Problem

Pacemakers are used to provide a timing and stimulation pulse of electrical energy to a failing heart. The pacemaker units consist of a small power and control source which is connected to the heart by an electrical lead. One type of electrode for contacting the heart wall consists of a helical coil of Elgiloy wire. This electrode material must be highly resistant to fatigue because of the considerable movement of the heart and the fact that the heart beats about 4×10^7 times per year. This electrode material must be implanted using surgery.

Another approach for planting the electrode in the heart wall is to run a fine wire (1 mm) through a hypodermic needle. The end of the wire has a small barb that fits against the end of the needle which is put through the chest wall and into the heart. When the needle is withdrawn, the barbed wire remains in the heart. The other end of the wire is attached to the power and control source which is placed outside the body. This general procedure is desirable for all electrode implanting because it does not require major surgery. This procedure is used for emergencies only because the wire will break shortly due to fatigue. The electrode and lead material are usually Elgiloy, but both stainless steel and platinum-iridium have proven unsatisfactory. However, adequate electrode material must be found; then the power and control source could be placed under the skin at a later date.

The researcher requires an electrode material suitable for implanting by the needle method. This material should be capable of withstanding the fatigue inherent in long-term (5 years) implants and must be compatible with human tissue.

Description of Solution

The solution involves the use of Nitinol alloy, a material with a mechanical memory. If Nitinol is annealed in a particular shape and then, after cooling, deformed, the annealed shape can be obtained simply by heating the alloy above the critical temperature. This critical temperature can be adjusted from -10°C to 100°C by changing the alloy constituents.

A Nitinol wire will be annealed into a coiled wire configuration with a helical coil on the end. This helix will be the barb that holds the electrode

in the heart wall and the coiled wire configuration will reduce the fatigue problem. The critical temperature of the alloy will be below body temperature and the wire straightened and put through the hypodermic needle. The needle will be placed through the chest and heart wall. The needle will be removed and as the wire is heated, it will form the permanent configuration.

Nitinol has excellent fatigue properties and the biocompatibility is being determined by Battelle Memorial Institute. Otherwise, the material appears to have all the necessary requirements.

Successful Searching Method

This problem was circulated as a Problem Abstract to the NASA Centers. Numerous suggestions were received from Lewis Research Center, Jet Propulsion Laboratory, Marshall Space Flight Center, and the AEC-NASA Space Nuclear Propulsion Office. Each suggestion was discussed with Dr. Morris and the suggestion selected for further study, the use of Nitinol alloy, was received simultaneously from Dr. J. G. Fisher of Jet Propulsion Laboratory, Mr. D. J. Winslow of Marshall Space Flight Center, and Mr. William Klopp of Lewis Research Center.

The team contacted Mr. W. J. Buehler of the Naval Ordnance Laboratory who supplied a sample of this material for preliminary tests. Mr. Buehler also agreed to make a special melt of this alloy to obtain the particular critical temperature required for this application.

The team acted as a catalyst to bring Dr. Howard Clark of the Duke Biomedical Engineering Department and Dr. Morris together. Dr. Clark will supply the necessary engineering expertise during the fabrication phase of this project.

The team also supplied a report, NASA CR-1433 "Nitinol Characterization Study" by Goodyear Aerospace Corporation, which describes the properties of this material.

Dr. Morris and Dr. Clark have now begun the fabrication phase of the testing in this project using the wire supplied by the Naval Ordnance Laboratory.

Benefits to be Derived from Transfer

Pacemakers are implanted in about 13,000 people per year in this country. As a result of this transfer, the researcher is starting the long series of tests necessary to verify this material as a replacement for the existing material. If these tests are successful, many people will be able to have pacemakers implanted by a simple injection of a hypodermic needle instead of the major surgery now required. This will be a significant advance in medical technology.

T R A N S F E R R E P O R T

RTI/IRM-3

"An Improved Spiral Brace"

Mr. H. Richard Lehneis, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1969
Transfer Made - January 1970
Elapsed Time - 9 Months

Description of Problem

Researchers at the Institute of Rehabilitation Medicine have designed a spiral leg brace which is prosthetically simple and functionally very effective. Unfortunately, the leg brace as presently constructed is subject to breakage in a short time of use of approximately three months. The design has proven to be a major breakthrough and solving the breakage problem would make the brace available to the public. The brace is now constructed of a material known as nyloplex, which is a cold polymerization product belonging to the acrylic glass family. The properties of nyloplex are: thermoformable, nonreactive to organic solvents, flexural modulus of approximately 7×10^5 psi, and available commercially in various sheeting thicknesses. An improved material is desired which can withstand the continual flexing required by the spiral brace without breakage.

Description of Solution

After this problem had been identified and preliminary searching had been accomplished, the problem was closed because it was thought that there was a small probability of finding a material that had been developed within NASA which could be successfully applied to this problem. Subsequently, the problem was discussed further with the researcher by the team member. During these discussions, it was suggested that perhaps the material now used for the brace could be employed if the physical configuration of the brace was modified. Further discussions were held, and a modified brace design was suggested. This suggestion was implemented, and a brace with the changed configuration was fabricated. The unit is currently undergoing tests. Preliminary results indicate that the breakage problem has been eliminated or at least significantly reduced.

Successful Searching Method

Manual search.

Source of Solution

The interface between engineering/technology and the biomedical community provided by NASA in the form of the Biomedical Application Team program was the instrument whereby this transfer was effected.

Benefits to be Derived from Transfer

Solution of the breakage problem will permit the use of the spiral brace in clinical practice at the Institute of Rehabilitation Medicine. This brace is lighter, more comfortable, less expensive, and cosmetically more desirable than previously used braces, thus improving patient acceptance and lowering cost.

T R A N S F E R R E P O R T

RTI/IRM-7

"A Material for Use in Direct Contact with the Blood Which Exhibits Reduced Clotting Characteristics"

Mr. Myron Youdin, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1969
Transfer Made - November 1969
Elapsed Time - 7 Months

Description of Problem

Mr. Youdin, a research scientist at the Institute of Rehabilitation Medicine (IRM) is collaborating with other researchers at IRM in the design of advanced biomedical instrumentation and devices. One of the units which Mr. Youdin has designed is a permanent-magnet blood flowmeter. The flowmeter is used on experimental animals and is implanted by severing the blood vessel and placing the flowmeter in line with the blood vessel. Blood flowing through the blood vessel, consequently, flows through the flowmeter body. Difficulties have been experienced with clotting of the blood in the regions where the blood is directly exposed to the flowmeter body. Various materials, such as polystyrene, Teflon, along with a heparin coating on the inside of the flowmeter body, have been tried experimentally with no consistent results. Long-term usefulness of the implantable blood flowmeter would be greatly enhanced if the body of the flowmeter could be rendered resistant to clotting for long periods of time.

Description of Solution

Recent work with vitreous carbon indicates that this material appears to meet the requirements of this problem. Vitreous carbon has been successfully tested as a percutaneous lead material (a lead which passes through the skin of an animal) by Mr. Jim Benson of Biocarbon, Tarzana, California (formerly with North American Rockwell). A number of other experiments have been made by various researchers indicating the biocompatibility of carbon materials.[1] Others have employed carbon coatings on materials exposed to the blood in order to reduce clotting.

Mr. Benson was contacted concerning the potential use of vitreous carbon as applied to this problem. He generously agreed to fabricate a vitreous carbon flowmeter body for use in experimental animals.

Mr. Youdin is completing fabrication of the flowmeter. Upon completion, the unit will be implanted in a dog to determine whether long-term monitoring of blood flow, without clotting of the blood, can be achieved.

[1] R-7855, "Presurvey on Biomedical Applications of Carbon," Jim Benson, April 28, 1969, North American-Rockwell, Rocketdyne Division, Contract No. NAS8-5604.

Successful Searching Method

Manual Search.

Benefits to be Derived from Transfer

Long-term monitoring of blood flow is very important in many animal experiments involving the cardiovascular system. The permanent-magnet blood flowmeter has great potential for providing this information since it can be used for long-term implantation once the materials problem with respect to blood clotting is solved. Conventional electromagnetic flowmeters require relatively large amounts of power to operate the electromagnets in the probe. Because of this power requirement, long-term implantation has not been very practical. The permanent-magnet flowmeter with its lower power requirements can be implanted for relatively long periods. One of the significant advantages of this totally implantable blood flowmeter is that it can be used with active, unrestrained animals, an achievement hitherto extremely difficult to accomplish.

T R A N S F E R R E P O R T

RTI/IRM-8

"Low Temperature Lubricant for Microtomes"

Dr. Shakuntala Chaube, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1969
Transfer Made - November 1969
Elapsed Time - 7 Months

Description of Problem

Dr. Chaube is one member of a team at the Institute of Rehabilitation Medicine (IRM) studying the congenital disease spina bifida in children. Spina bifida is a congenital defect in the closure of the spinal canal. Its causes are not known. Recent surgical procedures and hyperbaric oxygen therapy have prolonged the life of patients, but they still require an enormous amount of rehabilitation, time, and facilities.

Part of the research in this area involves the injection of chemicals into experimental animals--in this case, mice. The mice are then frozen whole and thin tissue sections are prepared for study. In order to section the frozen mice, it is necessary that the entire microtome be operated in a cold box. The conventional lubricants supplied with the microtome become sufficiently viscous at these temperatures such that operation of the microtome becomes difficult and performance in uniformly preparing thin sections becomes erratic. As a result, usable tissue sections are extremely difficult to prepare. The lubricant must be useful over the range -70°C to +80°C.

Description of Solution

Solid film lubricants employing molybdenum disulfide are described in a NASA SP-5059 document, "Solid Lubricants." The specifications of these solid film lubricants indicated their potential usefulness in this application. The commercial literature on lubricants was surveyed and a commercially available molybdenum disulfide solid film lubricant was identified. The lubricant, Dow Corning Spray-Kote bonded lubricant, was purchased by the researcher and a series of trials was conducted. The microtome functioned very well, and acceptable tissue thin sections were easily obtained.

It should be noted that this solution is identical to transfer No. UNC-12; however, the researcher is working in a different field of research.

Successful Searching Method

Manual search of NASA document files at Regional Dissemination Center.

Benefits to be Derived from Transfer

The direct benefits of the transfer are that the researcher can now easily obtain usable thin tissue sections. Previously, much professional and support effort has been directed toward trying to produce acceptable sections. Significant time savings in the preparation of sections have thus been effected.

T R A N S F E R R E P O R T

RTI/IRM-20

"Prevention of Orthostatic Hypotension"

Dr. Augusta Alba and Dr. Frieda S. Trainor, Goldwater Memorial Hospital, New York University Medical Center

Team Member - Ernest Harrison, Jr.

Problem Acquired - August 1969
Transfer Made - September 1969
Elapsed Time - 1-1/2 Months

Description of Problem

Researchers at Goldwater Memorial Hospital of New York University Medical Center have encountered a patient suffering from orthostatic hypotension. The underlying cause is suspected to be neural damage. Complicating this condition is the fact that the patient had previously sustained a hip injury which resulted in the left hip being fused in extension. With the hip fused, the patient could only stand or lie down. The occurrence of orthostatic hypotension now prevents the patient from standing; consequently, the only position the patient can assume is a reclining one. All attempts to bring the patient to an erect position using a tilt table, elastic bandages, and abdominal binders have been unsuccessful. Prior to this operation, the patient was able to walk with forearm crutches. She has the power in all extremities to maintain herself in the erect position if she could maintain her blood pressure. Although this problem concerns only one specific patient, there are, no doubt, numerous other people who could benefit from a technique that would permit people with orthostatic hypotension to stand erect.

The researchers feel that a pressure suit for the waist down (one that essentially fits the legs) in which the degree of counterpressure can be controlled may be more effective in combatting the patient's difficulty than the measures already employed. The researchers are interested in the availability of a pressure suit that could be used in this application. This request has been made of the Biomedical Application Team because of the widespread work of NASA in development of G-suits and pressure suits for the aerospace program.

The dimensions of the patient are:

waist	40"
hips	44-1/2"
right lower extremity (hip joint to sole of foot	36"
left lower extremity	36"
right thigh (maximum)	22"
left thigh (maximum)	26"
right ankle	7-3/4"
left ankle	8-1/2"
shoe size	7-1/2 C

Description of Solution

The pants section of a G-suit, such as the type worn by jet fighter pilots, was obtained on a loan basis.

Successful Searching Method

Manual search.

Source of Solution

Mr. John Samos, Technology Utilization Officer at NASA Langley Research Center obtained a G-suit on a loan basis. It was given to the researchers to permit experimentation with the G-suit on the patient.

Benefits to be Derived from Transfer

Use of the G-suit will permit the researchers to determine experimentally whether a pressurized suit can be successfully employed to correct the difficulties encountered by the patient in reaching and maintaining an erect position. In preliminary tests, a significant increase in the patient's ability to withstand elevation on a tilt table was recorded, indicating that the pressure suit concept may be useful in this particular problem. Previously, the patient had not been able to withstand 55^{o} elevation. Because of the prolonged bedrest of the patient, a conditioning program is necessary to determine the actual usefulness of this approach. If feasibility of the pressure pants is established, then custom-fitted pressure pants will be procured from commercial sources.

T R A N S F E R R E P O R T

RTI/NCSU-6

"Analysis Techniques for EEG Data"

Dr. Thomas E. LeVere, North Carolina State University

Team Member - F. Thomas Wooten, Ph.D.

Problem Acquired - March 1969
Transfer Made - November 1969
Elapsed Time - 8 Months

Description of Problem

The researcher has a general interest in the sleep process. Sleep or the lack of sleep can cause changes to occur in both the physiological and psychological processes of man. Sleep is a necessary requirement for man, but much information is needed about the processes that occur during sleep. For example, it is known that during sleep arterial blood pressure falls, pulse rate decreases, skin vessels dilate, activity of the gastrointestinal tract increases, and metabolic rate drops by 10 percent. Of greater interest is what activity changes occur in the brain during sleep because this is the control center for the physiological system.

One method for studying the activities of the brain is to use the electroencephalogram (EEG) which is a record of electrical potentials or activity on the surface of the head. Obtaining the EEG consists of placing electrodes on the head and recording the low voltage signals generated by the brain. These signals can be used as a measure of such things as depth of sleep, adaptation to noise, etc.

One of the difficulties in interpreting EEG data is the complexity of the signal. An EEG record is a low-frequency signal that is usually analyzed using a digital computer. Techniques for temporal frequency analysis are used.

The researcher was aware of much of the information in this field regarding EEG analysis. He wanted a search performed to apprise him of all developments in the techniques for low-frequency signal analysis. At the suggestion of the team, the search included analysis techniques for all types of low-frequency analog signals (i.e., seismographic).

Description of Solution

The team performed a computer search, Search No. 1656, "EEG Signal Analysis," of the aerospace data bank which disclosed 26 articles of interest to Dr. LeVere. Although many of the articles disclosed in the search appeared valuable, article No. A67-81357, "Evoked Responses and Reaction Time," was of major importance. This article discussed the use of computer averaging techniques to record evoked responses to certain sensory stimuli and concluded that evoked responses were correlated with reaction time.

The information disclosed in the search has been used by Dr. LeVere in his research and in the preparation of a proposal to the National Institute of Mental Health.

Successful Searching Method

Computer search at Science and Technology Research Center located at Research Triangle Park, North Carolina.

Benefits to be Derived from Transfer

This transfer has added knowledge to the research effort in this important phase of behavioral sciences.

T R A N S F E R R E P O R T

RTI/WF-31

"A Servo-Controlled System to Measure the Partial Pressure of Oxygen and Carbon Dioxide in Expired Gases and to Control the Operation of Respirators"

Dr. R. A. Kemp and Dr. J. H. Meredith, Bowman Gray School of Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - March 1968
Transfer Made - January 1970
Elapsed Time - 22 Months

Description of Problem

A control system for respirators is desired which can control both the rate of respiration of a patient and also the volume of air supplied to the patient during each breath. At least two types of patients would benefit from such a device. The first type involves the use of respirators on patients following extensive surgery and patients in intensive care units where the lungs are either not operating efficiently or it is necessary to reduce the work load by means of a respirator. The second situation involves treatment of patients who have normal lungs but who through some circumstance (for example, hypersensitivity to drugs) have temporarily lost the ability to breathe; i.e.,the control mechanisms which regulate respiration are temporarily inactive.

It is generally felt that the treatment of such people could be done more efficiently and without the danger of overventilation if a means of sensing the components of the expired gases could be implemented in such a fashion as to control the operation of the respirator to achieve proper respiration of the individual. Overventilation of the lungs is not only undesirable, it can be positively harmful. Essentially, the system would be required to sense the oxygen and carbon dioxide partial pressures in the inspired gas and expired gas. Inspired gas has a carbon dioxide content of nominally zero, with an oxygen partial pressure of approximately 150 mmHg. The expired gas, on the other hand, has a carbon dioxide content of from 42 to 58 mmHg and an oxygen content of approximately 100 mmHg. Five percent accuracy in sensing these compositions would be acceptable.

Although not a primary requirement of this problem, an additional desirable feature would be a control system which could program the operation of the respirator to achieve optimum respiration of the patient based upon the data provided by the carbon dioxide and oxygen sensors.

Description of Solution

A quadrupole mass spectrometer developed by NASA has been identified as being more than adequate for sensing the oxygen and carbon dioxide partial pressures. This unit, however, is not available through NASA and is not yet

commercially available. Further, specialized quadrupole mass spectrometers based on this design are far too expensive for this particular application. A commercial mass spectrometer has been identified which also will fulfill the sensory requirements of this problem. Although it is much less expensive than the mass spectrometer developed by NASA, it is still relatively expensive for this clinical type of application.

A suggestion was received from Mr. John Samos, Technology Utilization Officer at NASA Langley Research Center which involved the use of fluidic devices to measure the components of atmospheric gases. Since the source of this technology was the Harry Diamond Laboratories of the Army, the "need-to-know" was established and a conference was held with members of their Biomedical Section. Specific details of the biomedical problem were outlined, and the possibility of using fluidic techniques in this particular application were extensively discussed. The net result of these discussions was that the techniques suggested by Mr. Samos could not be implemented without a costly engineering investigation. Even then, the probability of success in employing these techniques could not be considered certain. Such a development program would involve the expenditure of considerable amounts of effort and funds. The researcher has limited funding so that he cannot support such a development program even if the success of such a development program were assured. Consequently, within the present constraints under which the problem is defined, it does not appear that the application of fluidics techniques to this problem can be accomplished.

As a result of the information supplied on the various types of respiration sensors by the Biomedical Application Team, the researcher has decided that the mass spectrometer offers the best solution, as a means of sensing the composition of respiratory gases, to his particular problem and circumstances. Since the NASA mass spectrometer could not be made available to the researcher and because reengineering of the NASA design was too costly, the researcher turned to the commercial sources identified by the Biomedical Application Team. The researcher is presently investigating several commercially available mass spectrometers and discussing their specifications with the manufacturer's representatives preparatory to selecting and purchasing a commercial unit.

Successful Search Method

A computer search of the aerospace literature provided information on the NASA-developed mass spectrometer.

Source of Solution

The information obtained from the search of aerospace literature provided the researcher with sufficient information to permit him to choose the technique most applicable to this specific problem.

Benefits to be Derived from Transfer

Proper control of respirators so as to fulfill the respiratory requirements of the particular individual being ventilated is extremely important. Overventilation is harmful. In addition, studies have shown that pure oxygen or high oxygen concentrations cause harmful effects when exposure is for long periods of time. Significant amounts of research have been expended by NASA, as well as others, which document this oxygen toxicity. Implementation of respirator control on the basis of the respiratory requirements of the patient is a positive step toward reducing some of the hazards now associated with prolonged respirator use.

T R A N S F E R R E P O R T

RTI/WF-33

"Application of Biotelemetry Units to Intensive Care Areas"

Dr. R. A. Kemp, Bowman Gray School of Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - December 1967
Transfer Made - November 1969
Elapsed Time - 23 Months

Description of Problem

Members of the Department of Surgery of the Bowman Gray School of Medicine are interested in improving the quality of patient monitoring in the intensive care unit. The present intensive care unit has approximately 15 beds located peripherally around a central nurse station. Two hard-wire systems for monitoring ECG from two of the beds at the central nurse station are in use. Present equipment is extremely bulky, both in the patient's room and at the nursing station, and requires physical attachment of wires to the patient. Such bulky equipment around the bed is extremely inconvenient. The researchers are very interested in some means of reducing equipment size and complexity while, at the same time, improving the monitoring facilities. Specifically, they would like to monitor ECG and respiration rate from each bed at the central nursing station. It is very desirable that wires not be attached to the patient; therefore, a telemetry unit is necessary. A conventional electrode system can be used for the ECG; however, an investigation of the different approaches to monitoring respiration will be necessary to determine the optimum technique.

Description of Solution

Search No. 697 on biotelemetry which was updated was supplied to the researchers for their evaluation. In addition, information on the Ames Research Center miniature biopotential telemetry system was furnished in the form of the supplemental information brochure compiled by Ames. Evaluation of the Ames telemetry unit was very favorable, and it appears that the basic design will perform the telemetry function required. The researcher requested the Biomedical Engineering Department of the Bowman Gray School of Medicine to construct a biotelemetry unit based on the Ames biotelemetry system. Difficulty was experienced in obtaining some of the parts specified in the Ames drawing. This, coupled with personnel losses in the Biomedical Engineering Department which left no one available to fabricate the unit, caused the researcher to halt investigation of the Ames telemetry system. The familiarity with telemetry systems gained by the researcher and the Biomedical Engineering Department permitted selection of a commercial transmitter unit which could be relatively easily modified for use in this application. The researcher purchased the commercial unit, and the Biomedical Engineering Department is currently making the necessary modifications.

Successful Searching Method

The Ames Biotelemetry System was identified on an earlier problem by means of NASA Tech Briefs and personal visits to the Ames Research Center.

Source of Solution

Ames Research Center.

Benefits to be Derived from Transfer

Successful implementation of a biotelemetry system for use in the intensive care ward will greatly alleviate the crowded condition that currently exists there around the beds of the patients.

T R A N S F E R R E P O R T

RTI/WF-69

"Correlation Techniques"

Dr. George S. Malindzak, Jr., Bowman Gray School of Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - May 1969
Transfer Made - January 1970
Elapsed Time - 8 Months

Description of Problem

Information is desired on the application of correlation techniques to the data signals commonly encountered in cardiovascular research.

The researcher has a general interest in the computer processing and enhancement of cardiovascular data. A recent article in the open literature has indicated that correlation techniques can be applied to data obtained from a two-point velocity probe in a fluid stream so as to yield information on turbulence and diffusion in the flowing stream. After reading of these techniques, the researcher feels that they have potential value in a number of biomedical applications directly concerned with his research program in cardiovascular physiology. For example, in determining cardiac output by indicator dilution methods, it is important that the flow profile be laminar (not turbulent). A means of detecting the onset of turbulent flow would be of value in this application. A number of other potential applications can easily be listed. The researcher wishes to determine whether these techniques can be fruitfully applied in the field of cardiovascular physiology as a prerequisite to beginning a research program in this area.

Description of Solution

This problem was solved as a result of a conference at NASA Marshall Space Flight Center (Huntsville, Alabama) with Dr. Fritz Krause and Mr. Andrew Ellner. During this conference, Dr. Malindzak and Mr. Harrison presented the basic problem which involves the determination of whether correlation and autocorrelation techniques (time series analysis) can be applied to research in the biomedical field (specifically, the cardiovascular system) to extract more significant information from data currently being collected and processed. The biomedical aspects of cardiovascular research were presented to Dr. Krause et al.; Dr. Malindzak has concluded that correlation techniques indeed offer potential benefit in extracting more useful information from data currently being collected and processed. As a result of this NASA/researcher interaction, the researcher has begun a research program to explore specific biomedical problems to which correlation and autocorrelation techniques can be fruitfully applied.

Successful Searching Method

The solution to this problem resulted from a suggestion form submitted by Mr. A. J. Ellner at Marshall Space Flight Center. The form was seen by Mr. James Richards of NASA,TUD, who noted its similarity to Biomedical problem WF-69. Mr. Richards forwarded the suggestion form to the Biomedical Application Team member.

Source of Solution

Dr. Fritz Krause and Mr. A. J. Ellner, NASA Marshall Space Flight Center.

Benefits to be Derived from Transfer

As a result of the solution to this problem (i.e.,the establishment that correlation and autocorrelation techniques offer promise for extracting more useful information from biomedical data currently being collected and processed), the researcher has begun a program to identify specific problems related to the cardiovascular system to which correlation and autocorrelation techniques can be applied with a high probability of success. As these specific problems are developed, research programs will be instituted and means of applying correlation and autocorrelation analyses to these problems will be explored.

T R A N S F E R R E P O R T

RTI/VU-1

"Improved Material for Percutaneous Tubes for Blood Dialysis"

Dr. H. Earl Ginn, Vanderbilt University

Team Member - F. Thomas Wooten, Ph.D.

Problem Acquired - June 1969
Transfer Made - October 1969
Elapsed Time - 4 Months

Description of Problem

The kidneys are organs that remove impurities from the blood. The entire human blood supply is filtered through the kidneys about 20 times each day. It is estimated that about 60,000 Americans die from kidney disease each year. If serious kidney disease occurs, artificial removal of blood impurities (dialysis) is required using the artificial kidney through which the blood supply must be circulated.

A patient requiring dialysis must be connected to the artificial kidney twice a week. To facilitate this frequent connection, small tubes (cannulas) are connected to both a vein and an artery of the arm. These tubes are connected by a shunt which allows blood to flow in the body when the patient is not connected to the artificial kidney.

A problem arises when a tube intersects the skin (percutaneous tube). This break in the skin is often the site of infections because of an improper seal between tube and skin. The tube is normally constructed of silastic but an improved material is required which will prevent this infection.

The tube material should be compatible with body tissue and must allow adequate sealing of the skin. The material also must not cause clotting of blood.

Description of Solution

Vitreous carbon is a material which appears to meet the requirements for this application. This material has been successfully tested as a percutaneous lead material by Mr. Jim Benson of Biocarbon (formerly with North American Rockwell). Mr. Benson was contacted and he generously offered to fabricate a series of tubes for evaluation of blood compatibility. These tubes have been received by Dr. Ginn for implantation in dogs.

Successful Searching Method

Manual search.

Benefits to be Derived from Transfer

This transfer will enable the researcher to evaluate vitreous carbon as a percutaneous lead material for dialysis implants. If the evaluation proves successful, this will be a significant improvement in treatment of kidney disease which kills an estimated 60,000 Americans a year.

A.2. Impact Reports

Impact reports are included for the following 8 impacts which resulted during the period September 1969 to March 1970:

WF-68

70

IRM-1

4

10

15

21

26

I M P A C T

RTI/WF-68

"Electrodes for Exercise ECG"

Dr. Henry S. Miller, Bowman Gray School of Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - March 1969 (problem was rejected when defined)
Impact Made - July 1969
Elapsed Time - 4 Months

Description of Problem

The researcher, as a part of routine examination and clinical practice, obtains exercise electrocardiograms (ECG) from patients with suspected myocardial insufficiencies. Electrocardiograms are taken from patients as they run on a treadmill. The purpose of this test is to detect cardiac abnormalities in the patient, as evidenced by changes in the electrocardiogram during exercise. Frequently, such abnormalities can only be detected in the electrocardiogram during exercise, while resting electrocardiograms are essentially normal.

The exercise regimen may vary in vigor, depending on the health and age of the patient. The researcher has experienced considerable difficulty with conventional ECG electrodes in that they (a) become unattached due to perspiration and fall off, (b) loosen and move causing motion artifact, and (c) are generally noisy and unsatisfactory for use during exercise. The researcher seeks an electrode which is free of these problems.

Use Factor

The NASA spray-on electrodes manufactured by the Hauser Company and the Hauser paper-backed electrodes, which are modifications of the spray-on electrode, were suggested to the researcher. A sample electrode array of the paper-backed electrodes was obtained from Hauser and given to the researcher for experimentation. After use, the researcher determined that these electrodes offered no significant advantage over the original system, and consequently they were rejected.

As a result of periodic review of literature in the biomedical area, the Biomedical Application Team member found a reference to disposable skin electrodes which had been tried at Walter Reed General Hospital. The reference was contained in the January-March 1969 Quarterly Report of

the U. S. Army Biomechanical Research Laboratory, Walter Reed Army Medical Center, Washington, D. C. In this document, a commercially available disposable electrode was reported to be in current use in the Coronary Care unit at that hospital and was preferred to all other types. It was reported to be easy to apply, to last for three to five days in use, and to be compatible with monitoring and telemetry equipment.

A sample of these electrodes, trade-named "Mono-electrodes," was requested and received from the manufacturer, Zenco Engineering Corporation, 2939-42 North Halsted Street, Chicago, Illinois. The researcher tried the electrodes in his tests and found them to be very satisfactory and to solve most of his electrode problems. The researcher has purchased a supply of the electrodes from the manufacturer, and they are now in routine use in his laboratory.

I M P A C T

RTI/WF-70

"Underwater Telemetry"

Dr. James G. McCormick, Bowman Gray School of Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - June 1969
Impact Made - October 1969
Elapsed Time - 4 Months

Description of Problem

A means of telemetering EEG, heart rate, respiration, and temperature from free-swimming porpoises in large tanks is desired.

The porpoise has a remarkable physiology, particularly as related to his ability to make deep dives in the ocean and rapidly return to the surface. The adaptation of the porpoise's physiology to accomplish this feat is of great interest. The auditory physiology of the porpoise is very highly developed. The chemistry of sleep in the porpoise and how it relates to his physiology during deep diving is also of interest. The investigator in conducting a research project to obtain information on the free-ranging porpoise that will permit a better understanding of the unusual physiology of this animal. Specifically, he would like to instrument free-swimming animals in a tank so that the following data can be received and recorded. In order of importance, they are (1) EEG, (2) heart rate, (3) respiration rate, and (4) temperature.

A telemetry unit which can transmit all four signals is desired. It would be most desirable if the telemetry transmitter signal from the porpoise could be received directly outside the tank. An underwater system (using sonic techniques) is permissible, but perhaps not as desirable as a system in which the receiver can be placed outside the tank. The least desirable approach would be to attach a line and an airborne balloon to the porpoise with the transmitting antenna thus being kept above the water's surface. This approach would be acceptable only if significant reductions in equipment complexity and cost could be gained thereby.

The porpoise is a large animal and can be equipped with a harness to which equipment can be secured. Consequently, the size and weight requirements are not at all severe. The unit must, of course, be capable of operation in sea water.

Use Factor

Two searches were applied to this problem: One was "Biotelemetry" (No. 679), an old search that had been run for a previous problem; the other was "Underwater Telemetry" (No. M3P) which was specifically structured to this problem. The Underwater Telemetry search was very relevant, and the researcher requested a number of documents. In addition, the abstracts themselves were of value to the researcher in identifying for him other researchers working in this field. Dr. McCormick has moved from Bowman Gray School of Medicine to Princeton University and is temporarily with the New Jersey Bureau of Research in Neurology and Psychiatry. He expects to use the information in his research program when he has taken a permanent position.

I M P A C T

RTI/IRM-1

"Determination of Brace Socket Pressure"

Mr. H. Richard Lehneis, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1969
Impact Made - March 1970
Elapsed Time - 11 Months

Problem Description

The researchers wish to determine the pressure at all locations and times in a brace socket during the walking cycle. Present approaches to the problem have been to use pressure transducers at selected discrete points in conjunction with microcapsules imbedded in foam rubber or a foam plastic to determine the points at which highest pressures are impressed. Discrete pressure transducers have been used to determine the pressure in selected locations. Unfortunately, using discrete pressure transducers, it is possible to overlook areas of high pressure. The microcapsules give qualitative information; i.e., they indicate that a certain pressure has been exceeded, but provide no dynamic information concerning pressures in a brace socket. A dynamic measuring technique which will permit monitoring the forces applied to a brace socket over its entire surface during the walking cycle is desired.

Use Factor

The Biomedical Application Team conducted a search of the aerospace literature on this subject and delivered it to the researcher. In addition, a number of approaches to the problem were discussed in detail with the researcher. At the same time, the researcher has continued to experiment with an approach on which he has begun preliminary work. The researcher has found the search and the discussions with the Biomedical Application Team very useful. Although they have not resulted in a solution to the researcher's problem, he feels that they have confirmed his belief that the approach which he is pursuing is most likely to yield a solution to his problem and has given impetus to his development of a continuous chemical pressure transducer that quantifies static pressure at all regions simultaneously over large irregular surfaces.

I M P A C T

RTI/IRM-4

"An Improved Material for Construction of Self-Adjusting Braces"

Mr. H. Richard Lehneis, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1969
Impact Made - January 1970
Elapsed Time - 9 Months

Problem Description

An improved material for construction of self-adjusting brace sockets or an improved design of self-adjusting brace sockets is needed.

Researchers at the Institute of Rehabilitation Medicine have developed a brace liner that supports only when an axial load is applied. There is effectively no resistance to loads perpendicular to the faces of the brace liner. The configuration of the self-adjusting brace is designed to permit a standard brace to be used by a variety of patients with different-sized limbs. This particular type of self-adjusting brace would be very advantageous in below-knee fractures of the leg, for example. The current brace liner is made of Dow Corning Silastic 385 Elastometer. In its present configuration, the brace lining material will not withstand the loads encountered when the brace is applied to a patient. The silastic material is placed in such a fashion that shear loading results and the material tears.

It is desired to obtain (1) An improved rubber that will withstand the shear loading imposed by the present design or (2) an improved approach to the design of brace sockets which will permit proper fitting to different-sized limbs.

Use Factor

As a result of discussions of this problem with the researcher, the team member suggested the use of a new fluorosilicone rubber which has been recently introduced commercially by Dow Corning and General Electric. Specifications of the rubber were furnished to the researcher. He has ordered the Dow Corning 2332N fluorosilicone rubber and is now employing it in the construciton of new self-adjusting braces for evaluation.

I M P A C T

RTI/IRM-10

"Methods of Measuring Calcium"

Dr. N. Eric Naftchi, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - May 1969
Impact Made - January 1970
Elapsed Time - 8 Months

Description of Problem

The researcher is a biochemical pharmacologist. He is beginning a new series of investigations in which an important step will be the assay of calcium in body fluids and solids. Information on the various methods of measuring calcium in body fluids and solids which have been tested and proven is desired. Sufficient information on these measurement techniques is desired to permit an evaluation of the techniques. With this information, the technique most appropriate for use in his research program can be selected.

Use Factor

A computer search of the aerospace literature was made and delivered to the researcher. There were a number of relevant articles. Most of the relevant articles were published in sources available to the researcher. He has looked up those articles of interest. The information derived from the search, in conjunction with information from the open literature and private discussions with other researchers, was used to select the calcium-measuring techniques most appropriate to the researcher's investigation. The techniques selected were atomic absorption and mass spectrometry. The researcher has already procured the equipment from commercial sources.

I M P A C T

RTI/IRM-15

"Effect of Environmental Extremes on Skeletal Calcium"

Dr. Benjamin J. Kamrin, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - April 1969
Impact Made - November 1969
Elapsed Time - 7 Months

Description of Problem

The researcher is interested in effects of environmental extremes on skeletal calcium which may have been reported in the NASA literature. He is conducting basic research on spina bifida. Spina bifida is a congenital defect in the closure of the spinal canal. Its causes are not known. Recent surgical procedures and hyperbaric oxygen therapy have prolonged the life and patients, but they still require an enormous amount of rehabilitation, time, and facilities. Dr. Kamrin is seeking information on body calcium disturbances, their causes and effects, which might be correlated with spinal defects, such as spina bifida. There has been reported to be body calcium disturbances observed in astronauts that have been attributed to weightlessness. He has requested information on the effects of weightlessness and other environmental extremes on skeletal calcium.

Dr. Kamrin ordered, read, and evaluated 19 documents which were contained in Search Bibliographies No. 1706, "Calcium Metabolism During Weightlessness", No. 980 "Effects of Weightlessness on Skeletal Calcium", No. 1584 "Measurement of Astronaut Metabolism", and No. 1591 "Body Chemistry Under Stress".

Dr. Kamrin's work with spina bifida directly involves calcification processes. One of the purposes of the search was to reveal if aerospace research had produced data which could be correlated with his area of interest, i.e., spina bifida in children. He found much information on calcification in the search articles. Much of his information was rated as both of interest and valuable, even though no specific correlation between aerospace data on calcification and calcification processes and spina bifida could be made.

Use Factor

The information provided the researcher was of specific use in ascertaining that data which could provide correlation between calcification

processes and skeletal disorders, like spina bifida, had not been published in the aerospace literature. The information also had a potential use. The researcher is considering a research project on the fundamental aspects of the calcification process, without specific relationship to spina bifida. The information from the aerospace literature relating to calcification will be useful background and supporting information for these studies of the calcification process.

I M P A C T

RTI/IRM-21

"An Improved Splinting and Cast Material"

Mr. H. Richard Lehneis, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - May 1, 1969
Impact Made - March 24, 1970
Elapsed Time - 10 Months

Description of Problem

A lightweight, high-strength, easily fabricated splinting and cast material is desired. Large numbers of patients at the Institute of Rehabilitation Medicine require casts, custom-fitted splints, and orthotic devices. Much of the fitting requires shaping into complex contours. Perhaps the most widely used and most successful material is plaster of paris. It is quite time-consuming to construct these items from plaster. The finished items are relatively heavy and difficult to keep clean. Also the materials are not reusable. On the positive side, plaster of paris is inexpensive, and its strength and resistance to the mechanical shock and the temperatures normally encountered are generally adequate. A lightweight, inexpensive casting material which can be easily fabricated into intricate shapes is desired. Various plastic materials have been marketed as cast and splint materials, but none tested to date have all the desired properties. Most are expensive, difficult to form, and unable to withstand normally encountered direct sunlight and heat.

When made into a cast or splint, the material must have sufficient strength and shock resistance to properly support the patient and to withstand the impact forces that might normally be encountered. It should be able to withstand direct sunlight, hot water, and household chemicals.

Use Factor

As a result of Biomedical Application Team activities at Bowman Gray School of Medicine, it was discovered that a new orthopedic cast material was to be placed on the commercial market in the late summer of 1969. The cast material, trade-named "Litecast," basically consists of a special, soft, flexible, resin impregnated fiberglass tape which, after winding in place, can be hardened into a rigid, moisture-resistant cast using a special

lamp whose wavelength is such as to cure the resin. The manufacturer of the fiberglass tape supplied some to NASA on the Apollo program. After completing the NASA contract, the manufacturer maintained interest and developed an improved flexible fiberglass cloth which is used in the "Litecast" system.

The medical researcher has ordered the "Litecast" system, and it is expected to fulfill all the requirements of this problem.

I M P A C T

RTI/IRM-26

"A Means of Presetting Prosthetic Hands to Grip Objects With a Desired Force"

Mr. Warren Frisna, Institute of Rehabilitation Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - November 1969
Impact Made - March 24, 1970
Elapsed Time - 4 Months

Description of Problem

Powered prosthetic hands that are commonly available today grasp objects with a fixed force which is frequently either not adjustable or very difficult to adjust. Various devices have been tried. For example, slip clutches are sometimes incorporated in the drive train so that, when the hand grasps an object, the drive continues to close the hand until the force which corresponds to the slip clutch setting is exceeded. At that point, the clutch slips, and the force applied by the hand remains constant. Unfortunately, in rehabilitation it is desirable (because of the varying tasks that different people perform) that different prosthetic hands be capable of adjustment to provide different grasping forces. This is not easily accomplished with the slip clutches in use. In addition, the slip clutches themselves add mechanical complexity and expense to the hand. Other techniques have been tried, but most suffer from complexity, difficulty of adjustment, or high cost. What is desired is a very simple means of controlling the grasp of a prosthetic hand so that its grasping force does not exceed a prescribed limit.

The primary requirements placed on the solution to this problem are simplicity and low cost. Complexity and accompanying bulk will discourage use. In the clinical situation, even moderately high cost will positively prohibit use. In addition, the installation of the necessary control circuitry or device must be relatively easily accomplished to permit retrofitting to existing prosthetic hands. Further, the method of control selected must permit changing of the preset grasping force quickly and easily should the requirements of the prosthetic hand user change.

Use Factor

The Biomedical Application Team suggested the use of a commercially available pressure-sensitive paint in this application. The paint, manuafactured by Clark Electronics, 1365 E. Edinger Avenue, Santa Ana, California, can be applied to the pads of the thumb and forefinger (or other gripping surface) where it functions as a switch with the appropriate control circuitry. By varying the thickness of the paint applied, the prosthetic hand can be made to interrupt the drive circuitry at the desired gripping force. The pressure-sensitive paint has been purchased by the researcher and has been successfully employed to control the grasping force exerted by a prosthetic hand in the researcher's laboratory. The researcher considers this to be a very promising approach because of its simplicity and light weight.

A.3. Potential Transfer Reports

Potential transfer reports are included for two potential transfers active as of March 14, 1970:

WF-56

IRM-23

P O T E N T I A L T R A N S F E R R E P O R T

RTI/WF-56

"A Fluid Pressure Calibration System"

Dr. George Malindzak, Bowman Gray School of Medicine

Team Member - Ernest Harrison, Jr.

Problem Acquired - June 1968
Potential Transfer Identified - December 1969
Elapsed Time - 18 Months

Description of Problem

A system is required which can be used to calibrate pressure transducers employed by researchers and clinicians in their investigative and diagnostic procedures.

At the Bowman Gray School of Medicine there are a large number of pressure transducers of varying manufacture and design that are employed by investigators in their research program and by clinical personnel in the diagnosis and treatment of patients. A significant question that recurs with great frequency is, "Has my pressure transducer maintained calibration or is it now inaccurate?" Many of these transducers are inherently fragile; nonetheless they receive severe handling and are exposed to harsh environments. Consequently, the accuracy of a transducer is usually uncertain unless it is calibrated before each use. Since a calibration facility is not available at Bowman Gray, no doubt many transducers are used whose accuracy is no longer within specification.

To alleviate this situation the researcher desires to establish a calibration facility where the staff and faculty members of the Bowman Gray School of Medicine can determine the accuracy of the pressure transducers that are employed to obtain measurements in research and clinical practice.

Basically, the calibration unit would consist of a pressure wave generator, an accurate standard transducer, a pressure chamber, and appropriate manifolding. The fluid within the pressure chamber can be distilled water. Means of eliminating air bubbles in the chamber is necessary, because air bubbles seriously affect the pressure generated. The pressure generator must be capable of generating fluid pressures in its chamber from near zero to approximately one atmosphere of pressure (x 760 mm Hg gage). Frequency response of the pressure generator with a given pressure output should be constant ($\pm$5 percent) over the frequency range from 1/10 hertz to 150 hertz.

Commercial function generators are available for use in this system which have the desired frequency response. If these are used, a driver with characteristics tailored to the response of the selected pressure generator would be required.

If the output frequency response of the pressure generator cannot be held to ±5 percent over the frequency range from 1/10 hertz to 150 cycles, then a calibration curve for the pressure generator is acceptable. This, of course, is not as desirable as a constant frequency response.

Description of Potential Solution

A fluid pressure calibration system has been designed and fabricated at U.S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Texas. This calibration system was designed to meet a need at Brooks Air Force Base which is very similar to the application described in this problem. Details of the system are given in publication N68-25062.

Searching Method

When this problem was originally received, a search of the aerospace literature was made. No highly relevant information was found. Subsequent to this search, the document describing the system now proposed as a potential transfer was published. The document was found and identified by the Biomedical Application Team member as a result of routine searching of the STAR abstracts.

Source of Potential Solution

Document N68-20562 by Captain H. F. Stegall, USAF, MC, and a related document from the open literature by the same author.

Current Status

The researcher has evaluated the article and found the calibration system described herein to be an acceptable solution to the biomedical problem. Attempts have been made by the researcher to build the unit, but such efforts have been unsuccessful.

Prognosis for Actual Transfer

If a reengineering and fabrication source can be established within the researcher's constraints, the chances for a successful transfer are virtually 100 percent. The researcher is eager to implement this solution and place the system in operation immediately.

P O T E N T I A L T R A N S F E R R E P O R T

RTI/IRM-23

"A Respiration Alarm"

Dr. August Alba, Institute of Rehabilitation Medicine, N.Y., N.Y.

Team Member - Ernest Harrison, Jr.

Problem Acquired - September
Potential Transfer Identified - November 1969
Elapsed Time - 2 Months

Description of Problem

A simple alarm is needed to warn nurses in the event of respirator failure.

The Goldwater Memorial Hospital of the New York University Medical Center operates one of the largest respirator centers in the United States. Users of these respirators are permanently disabled, e.g., stroke victims, paralysis victims, and others permanently unable to respire themselves as a result of accident or disease. This means that the respirators must be used on the patients continuously and for long periods of time. The respirators have battery-operated alarms connected to their mechanisms which function when the respirator becomes disabled. The alarms are not foolproof, however, because the alarm system itself is subject to failure. Circuit failures can, and do, occur. In addition, the batteries that power the alarm system can become depleted without the knowledge of the nurse, and maintenance personnel must be relied on to insure that the batteries are always adequate. The result is that nurses do not fully trust the alarm system. This results in closer surveillance by the nurses and correspondingly requires more or their time. There have been reported cases in which patients have died, when respirators with faulty alarms become inoperative, before medical personnel become aware of the situation. As a result, a separate alarm system is desired, independent of the respirator alarm, which can sense when a patient is not being respired. It is desired that the alarm be attached to the patient and monitor some parameter that is a direct index of whether the patient is being respired or not. Sensing of even a mechanical parameter, such as change in volume of the chest with respiration, would be acceptable.

The alarm must be reliable. It must be sensitive enough to detect loss of respiration, but not so sensitive that frequent false alarms are given. If frequent false alarms occur, the unit will be turned off or ignored, and it will serve no useful purpose. Necessary attachments to the patient must not be so bulky as to cause the patient discomfort. In summary, simplicity, reliability, and low false alarm rate are primary requirements.

Description of Potential Solution

Two potential solutions to this problem have been identified. The first is a very simple and relatively crude solution. It involves the use of a microswitch on an adjustable belt which is placed around the chest of the respirator patient. The belt tension is adjusted so that the microswitch is closed when the patient expires and opens when the patient inspires. With suitable electronic circuitry an alarm can be made to sound if the switch stays closed for a preset time, thus indicating respirator failure. This represents a low-cost approach. Indeed, the attractiveness of this technique to the researcher lies in its simplicity and low cost.

The other proposed solution is more sensitive, more complex, and consequently, more costly. It operates on the principle of detecting the difference in temperature of the incoming and outgoing breath of the respirator patient. Because most of the patients at Goldwater Memorial Hospital are either in "iron lung" type respirators or the portable balloon type respirators, positioning and maintenance of position of the sensors may well be a significant difficulty in trying to implement this approach.

The investigator is interested in trying the microswitch approach first because of its low cost, simplicity, and ease of fabrication. Current plans are for technicians at Goldwater Memorial Hospital to fabricate a unit using the microswitch approach. This unit will be evaluated. If it successfully passes the evaluation, other approaches will not be considered. If it fails to meet the requirements, then further consideration will be given to the second approach.

Searching Method

The first solution was found as a result of routine manual scanning of the STAR bibliographies by the team member. The second solution had been identified in connection with previous respirator alarm problems by discussions with NASA TU personnel.

Source of Potential Solution

The source of the first solution was an abstract of a Russian document. The source of the second solution was Tech Brief 68-10365 and the associated Technical Support Packages which were received from Mr. George Edward, TUO, NASA, Ames Research Center.

Current Status

The researcher is seeking to have a unit fabricated using the microswitch approach.

Prognosis for Actual Transfer

Must await researcher's evaluation.

APPENDIX B

B.1. Problems Accepted During Period

September 1969 to March 1970

WF-73
74
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85
86
DU-59
61*
63
65
66
67*
68
BA-1
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3
4
5
6
TU-1
2
3
5
6
NCI-2*
3*
4*
6*
7
8**
NCSU-8
9
10
11
CP-1
2
3
4
IRM-23
24
25**
26
UNC-54
55
ESU-1
MCV-2
NIMH-1
MISC-3**
4

*Problem Statements circulated to NASA Field Centers.

**No Problem Statements have been prepared.

B.2. Problems Closed During Period

September 1969 to March 1970

Problem Number	Code*	Problem Number	Code*
RTI/DU-46	A	RTI/WF-24	B
DU-56	A	WF-28	K
IRM-1	M	WF-30	A
IRM-6	K	WF-36	J
IRM-21	M	WF-37	A
IRM-26	M	WF-42	B
UNC-47	D	WF-44	B
UNC-54	D	WF-46	I
UNCD-15	K	WF-48	I
UNCD-16	K	WF-50	A
UNCD-17	K	IRM-7	A
UNCD-18	K	IRM-8	A
UNCD-20	K	IRM-15	M
UNCD-21	K	UNCD-19	E
UNCD-22	K	UNCD-24	E
UNCD-23	K	UNCD-27	E
UNCD-25	K	WF-31	A
UNCD-26	K	WF-33	A
WF-32	K	WF-68	M
WF-40	K	WF-76	H
WF-41	H	IRM-4	M
WF-47	K	IRM-10	M
WF-59	B	IRM-16	C
WF-63	A	IRM-17	C
WF-69	A	IRM-20	A
WF-70	K	WF-65	C
WF-75	E	WF-66	C
DU-45	A		
DU-53	B		
MISC-2	B		
NCSU-10	K		
NCSU-11	K		

*See Table 3 on page 20 .

B.3. Problems Rejected During Period

September 1969 to March 1970

Problem No.	Title	Reason* Rejected
RTI/DU-60	"Brain Probe for Hypothermia Surgery"	A
DU-62	"Effects of External Electromagnetic Field Cells"	D
DU-64	"Temperature Control in Experiments on Small Tissue Samples"	A
DU-69	"Monitoring Methods for Intensive Care Unit"	A
IRM-18	"A Means of Inducing Localized Hyperthermia"	C
WF-78	"Method of Purifying Phospho-Ribomutase"	B
SV-1	"Intracranial Pressure Transducers"	A
TU-4	"Multichannel Telemetry System"	E
TU-7	"Dissecting Microscope"	A
MCV-1	"Applications of Image Processing Techniques to Radiography"	

*Key

A -- Solution commercially available
B -- Aerospace technology not relevant
C -- Beyond state-of-the-art; development project
D -- Low interest priority
E -- Problem confidential
F -- Facilities to implement solution not available

B.4. Status of Active Problems as of March 31, 1970

Problem Number	Problem Status	Problem Title
RTI/BH-1	B	Respiratory Measurement During Exercise
BH-2	B	Respiratory Gas Analysis During Exercise
BH-3	B	Blood Pressure During Exercise
BH-4	B	Blood Flow During Exercise
BH-5	B	ECG During Exercise
BH-6	B	Exercise Capacity and Standardization During Human Stress Testing
CP-1	B	Data Compression Techniques: Software
CP-2	B	Mathematical or Computer Methods for the Determination of Material Properties of Cardiac Muscle
CP-3	B	Automated Measurements from Coronary Angiograms
CP-4	B	Real Time Data Acquisition During Batch Processing
DU-31	D	Catheter-Mounted Pressure Transducer
DU-47	D	Urethral Pressure Transducer
DU-48	C	Urine Flowmeter
DU-58	B	Urine Disposal System
DU-59	D	Temperature Measurement on a Small Brain Probe
DU-61	C	Improved Resolution for X-ray Fluoroscopic Images
DU-63	B	Measurement of Single Nerve Cell Activity
DU-65	B	Strain Measurements in Ligaments
DU-66	D	Tissue Oxygen Monitoring During Childbirth
DU-67	C	Synthetic Resins for Cell Separation in Immunological Research
DU-68	D	Grooves in Glass for Cell Growing
IRM-2	B	A Body Power Energy Storage System
IRM-5	D	An Improved Flexible Lead Wire for Implantable Devices
IRM-14	D	Motion Force Amplifier
IRM-22	D	A Means of Tracking Eye Movements While Viewing Printed Matter, Geometric Forms, and Pictures
IRM-23	E	A Respiration Alarm
IRM-24	D	Waste Management Technique
IRM-25	D	Small Battery-Operated Suction Pump
LSU-1	B	Improved Artificial Respirators

Problem Number	Problem Status	Problem Title
RTI/MCV-2	B	High Intensity Soft X-Ray Sources
MISC-3	A	Mechanism for Operating Piano Pedals
MISC-4	B	Freezing Unit for Smallpox Vaccine
NCI-1	C	Noise Reduction in Laminar Flow Rooms
NCI-2	C	Lactate/Pyruvate Measurement in Blood
NCI-3	C	Blood Pressure Measurement
NCI-4	C	Controlled Rate of Freezing a Liquid
NCI-6	C	Separation of White Cells
NCI-7	B	Method of Fast Warming of a Frozen Liquid
NCI-8	A	Elliptical Lens
NCSU-9	D	Analysis Techniques for Physiological Data
NIMH-1	B	Urination Detection
TU-1	D	Shock Wave Measurement
TU-2	D	Respiration Rate Measurement
TU-3	B	A Lung Sound Detection
TU-5	D	Measurement of Change in Heart Wall Dimensions
TU-6	B	Measurement of pCO_2, pO_2, pH in Blood
UNC-50	D	General Purpose, Indicating, Pressure-Sensitive Muscle Trainer
UNC-55	B	Non-Contacting Method for Human Infant Position Determination
WF-29	D	An Electrode for Measuring Hydrogen Ion Concentration and CO_2 Partial Pressure in the Blood is Needed
WF-53	B	Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins
WF-56	E	An Improved Fluid Pressure Calibration System
WF-61	B	An Improved Method of Determining Volume Elasticity of Blood Vessels
WF-62	D	An Extremely Thin Pressure Transducer to Measure the Pressure Exerted on Tissue by Support-Type Hosiery
WF-64	B	Improved Method of Making Volume Plethysmographic Measurements Related to Volume Changes in Tissue Caused by Influx and Efflux of Blood During the Cardiac Cycle
WF-67	B	A Filter to Separate Physiologic Data Occurring at Nominal Heart Rates from Lower Frequency Data
WF-72	D	Automatic Control System for a Tilt Bed
WF-73	B	Determination of the Site of Bleeding in the Intestine
WF-74	D	Assay of Amino Acids in the Brain

Problem Number	Problem Code	Problem Title
RTI/WF-77	D	A Means of Measuring Evaporative Heat Loss from the Skin
WF-79	D	Computer Processing of Chromosome Data
WF-80	D	A Miniature Infusion Pump
WF-81	B	A Means of Detecting Turbulence in Blood Flowing in a Tube
WF-82	B	Prevention of Tip Washout in Dye Injection Techniques
WF-83	D	Identification of Infrared Spectra Using Computer Techniques
WF-86	B	Reduction of Anxiety by Noncontacting Stimulation

Key to Problem Status Designation

A. Problem Definition

Problem definition includes the identification of specified technology-related problems through discussions with biomedical investigators and the preparation of functional descriptions of problems using nondisciplinary terminology.

B. Information Searching

Information relevant to a solution is being sought by computer and/or manual information searching.

C. Problem Statement Circulation

An information search has revealed no potential solutions, and a problem abstract is being circulated to individual scientists and engineers at NASA centers and contractor facilities to solicit suggestions.

D. Evaluation

Potentially useful information or technology has been identified and is being evaluated by the team and/or the problem originator.

E. Potential Transfer

Information or technology has been evaluated and found to be of potential value but has not been applied.

F. Follow-up Activity

A technology transfer has been accomplished, but further activity (i.e., documentation, obtaining experimental validation of utility, continuing modification, etc.) is required.

APPENDIX C

Problem Statements Circulated to NASA Field Centers During the Period September 1969 to March 1970.

P R O B L E M S T A T E M E N T

"Urine Flowmeter"

What is Needed

A flowmeter is required for measuring urine flow in the ureter.

Background

Kidney diseases are quite varied but they attack all age groups and cause the death of 60,000 Americans each year. In order to understand these diseases, an improved understanding of the urological system is necessary. One of the parts of the urological system of particular interest is the ureter, i.e., the tubes that connect each kidney to the bladder. Urine flow measurements in the ureter are being used in a research study to understand ureteral physiology. Improved flow measurement techniques also could be used in clinical studies of kidney, ureteral, and bladder diseases. All existing techniques for measuring flow in the ureter involve collecting samples of urine over definite intervals of time and calculating average flow rates. These average flow measurements are not satisfactory when the pulsatile nature of flow in the ureter is being studied. This pulsatile flow of urine is felt to be very important in obtaining a better understanding of ureteral physiology. Urine flows through the ureter in small ellipsoidal masses, each of which is called a bolus. Each bolus leaves the kidney and is transmitted as a unit to the bladder through the ureter. Thus, at a given point in the ureter, an observer would see a series of bolus passing the particular point at a rate of about 1 to 5 per minute. This is the nature of the pulsatile flow in the ureter.

The requirement here is for a technique for measuring instantaneous rates of urine flow in the ureter. The transducer can be used either internally or externally. If an external transducer is used, the flow of urine can be diverted to a point outside the animal's body using a catheter. If a catheter is used, the size must be less than 2 millimeters so that the flow characteristics are not disturbed.

Requirements and Specifications

The flowmeter should measure transient urine flows of from 1 to 100 cc/min with an accuracy of $\pm$ 1%. The pressure varies from 0-20 mm Hg. Size of the flowmeter is not important because the flowmeter can be outside the body. However, if the flowmeter is used in the body, the diameter must be less than 2 millimeters.

Characteristics of Relevant Technology

(Note: This section is illustrative only, and is not intended to bias the suggestion of potential solutions.)

Any liquid flowmeter method would be useful. Ultrasonic doppler techniques have been considered but will not work because urine does not contain small particles. Electromagnetic techniques might work if improved sensitivity over existing commercial units can be found.

References

A computerized literature search of NASA's aerospace information bank has been performed and the below-listed references were identified which appear to be applicable to the problem. However, many relevant references may not have been identified by this means, and any additional suggestions will be appreciated.

1. N67-20763, "Magnetic Flowmeter Calibration" by D. D. Bluhm, R. W. Fisher and D. L. Smith.
2. N67-20220, "Electromagnetic Flowmeters" by M. Hori, T. Kobori and Y. Ouchi.
3. A67-13775, "Precise Measurement of Unsteady Fluid Flow" by L. N. Randall
4. N66-25826, "Microwave and Sonic Methods for Measuring Liquid Level and Flow Rate" by K. R. Carr and J. U. Clark
5. A69-15030, "Primary Flowmeter" by P. D. Dieterich
6. N68-28684, "Nuclear Magnetic Resonance Flowmeter" by W. S. McCormic.

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P R O B L E M S T A T E M E N T

"Improved Resolution for X-ray Fluoroscopic Images"

What is Needed

Improvement in image quality and resolution is desirable in medical X-ray fluoroscopy. Improvement in convenience of use and a lower X-ray dose to the patient are also highly desirable.

Background

The use of X-rays to examine internal structure of the body is one of the fundamental techniques in clinical medicine and any improvement would have obvious and immediate importance. Although striking changes in X-ray sources are expected eventually (i.e., high intensity flying-spot X-ray tubes, or coherent sources of X-rays), it is the imaging and display system which is the subject of this problem statement.

Existing medical X-ray examinations use one of the following image displays: (1) image formation on photographic film, often backed by a phosphorescent screen; (2) image formed directly on a phosphorescent screen (or fluoroscopic screen) for direct viewing; (3) image formed on a fluorescent screen followed by an electronic image intensifier. Radiography, the use of X-ray film, has very high image quality and resolution but is not suited for following time-dependent events and introduces delays through the necessary film processing. Direct fluoroscopic screen examinations use simple, reliable, relatively inexpensive apparatus, but must be performed in a dark room by a dark-adapted physician and require high patient X-ray doses. Electronic image intensification of the fluoroscopic screen image permits observation of time-changing events without the necessity for prior dark-adaptation and uses tolerable total X-ray doses, but the apparatus is complex, expensive, and bulky. The image intensifier tube restricts the area of examination to a 9-inch diameter circle, and restricts the physician's movements and access to the patient.

The researchers have asked a general question concerning the possibility of any improvement in image quality in image-intensified fluoroscopy. Their question was asked in the context of heart catheterization, angiography, and general observation of time-varying processes, but possible improvements in radiography should also be of strong interest to them.

Requirements and Specifications

For medical imaging applications, a large sensitive area (preferably 12-inch diameter or greater) and high sensitivity to X-rays (typical energy 60 KeV) are desired. The time constant for image buildup may vary depending on the specific application, but should not be longer than one second. Simplicity, compactness, ease of use, and low cost per examination are all desirable. Dose rate to the patient should be minimized.

Estimates of radiation level and resolution in current practice are supplied here only as rough guidelines: dose rate of 2-17 roentgen/minute for 3-10 minutes examination period in direct fluoroscopic screen examinations, with a dose rate reduction by factors 10-100 for image intensifier use; and typical resolution distances of 10^{-3} mm for film and 0.5-1.0 mm for fluoroscopic screens. If closed-circuit TV display of the final image is used, there is further image degradation by the standard 525-line system.

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P R O B L E M S T A T E M E N T

"Synthetic Resins for Cell Separation in Immunological Research"

What is Needed

A method is needed for separating from a heterogeneous cell population only those cells capable of certain immune responses to various antigens. A proposed approach would use a synthetic resin or other appropriate material as a substrate onto which an antigen could be adsorbed; utilizing the phenomenon of immunoadherence, the desired cell separation may be achievable on the basis of the specific gravity of the synthetic resin. In short, this is a materials problem and the researchers want an appropriate material to try. The properties of the material are given in the "Requirements and Specifications" section of this problem statement, and the immunological aspects are presented immediately below.

Background

Immunology is the science dealing with the phenomena and causes of immunity. The transplant rejection phenomena of such concern in this age of heart and kidney transplants are different manifestations of the same underlying immune reaction phenomena upon which the familiar preventative innoculations against diseases are based. For all the practical successes of immunology, a true understanding of immune reaction processes at the cellular and the molecular levels is only now beginning to emerge. The cell separation method of this problem statement is needed for basic research on antigen-antibody reactions involving a specified antibody; at present the researchers cannot avoid dealing with a heterogeneity of antibodies.

Fundamental terms are antigen and antibody. An antibody is any of a number of body globulins (a class of proteins) normally present or produced in response to the administration (deliberate or accidental) of antigens. Antigen is a general term denoting anything which can cause antibody generation; antigens are, in effect foreign substances from the body's viewpoint and antibodies are part of the body's defense mechanism against foreign substances. There is high specificity of antibody response, with only certain antibodies reacting with a given antigen and other antibodies responding to different antigens. (This is not absolute as antibodies do cross-react with various antigens. Cross-reactivity is based upon chemical similarity of the antigens with more similarity implying more cross-reactivity and vice versa.) The response or reaction itself is varied, but in general the specific antigen-antibody reactions lead to modified subsequent histories for the various antigens. Antibodies are found as globulins circulating in blood serum and also as a surface component of various lymphoid cells. Antibodies are produced by lymphoid-derived cells in various organs, in particular the spleen, lymph nodes, and bone marrow.

In the problem at hand, we are interested in antibodies present on the surface of lymphoid cells, antibodies which might be produced in response to a number of potential antigens. The investigation is concerned with separation from the general lymphoid population those cells having antibody specificity

for only one antigen. The researchers are attempting to make use of a phenomenon called immunoadherence for this separation. In this system a desired cell is identified by the adherence to its surface of particles onto whose surfaces have been incorporated the antigens of interest.

In the method now under investigation, the mouse is the experimental animal and the antigen with which the mouse is immunized is the sheep red blood cell (called SRBC hereinafter). In response to an initial injection of SRBC, the mouse generates antibodies specific to the antigens at the SRBC surface (unfortunately several antigens are simultaneously present in the SRBC; this heterogeneity of antigen is the principal drawback). Four to ten days after the initial injection the mouse is killed and the white blood cells, or leukocytes, are extracted from its spleen. When these leukocytes are mixed with more SRBC, the leukocytes carrying SRBC-specific antibodies form rosettes through immunoadherence; a rosette consists of one mouse spleen leukocyte with a number of SRBCs, perhaps 10-15, distributed over its surface. A single SRBC is a biconcave disk 5 microns in diameter and a micron or two thick; and a leukocyte is roughly spherical, 7-20 microns diameter, with the rosetting leukocytes of interest being 12-14 microns in diameter. The specific gravity of SRBC is greater than that of the leukocyte and a partial separation of rosetting leukocytes from the background population of millions of indifferent leukocytes can be achieved[1,2] by centrifugation in a discontinuous density gradient. A complete separation is desired; the researchers have a future series of experiments to perform with leukocytes free of a specific antibody and another series to perform using leukocytes guaranteed (by having rosetted) to have a specified antibody present.

One reason that the above method is not satisfactory is that the separation is inefficient and incomplete and depends strongly upon factors difficult to control. Results vary even by using bovine serum albumin (one of the materials which can be used to form the discontinuous density gradient) from different commercial sources. A more fundamental objection is the heterogeneity of SRBC as antigen; a separation of leukocytes is needed based on single defined antigens. A modification of the method is desired using a substitute for SRBC which would have a high surface adsorption for a number of different single antigens, and the specific gravity of this substitute is as specified below to permit greater ease of separation following centrifugation (the substitute material will float above the leukocytes). If an appropriate substitute can be found, probably a plastic or synthetic resin, and a complete cell separation can be then achieved, the ultimate result will be a very clean and convincing set of experiments capable of confirming or rejecting basic theories in immunology.

Requirements and Specifications

The goal is a substrate, probably a synthetic resin, which has high surface adsorptivity for single antigens and whose physical characteristics (specific gravity in particular) lead to subsequent separation of the antigen-specific antibody-carrying leukocytes from the remainder of the mouse spleen leukocytes. Some of the characteristics of the desired material are:

[1]K.A. Dicke, J.I.M. Van Hooft, and D.W. Van Bekkum, Transplantation, 6, 562, (1968).

[2]N. Moav and T.N. Harris, Proc. Soc. Exp. Biol. Med., 128, 407 (1968).

1. It should be capable of formation into microspheres about 5 microns in diameter and uniform in size to within a micron or two;
2. It must be possible to adsorb onto the surface (or else react onto sidegroups) of the microsphere material, a variety of antigens,[3] such as proteins like bovine or human albumin;
3. The microspheres must be relatively impermeable with antigen adsorption only at their surfaces;
4. The material must have uniform electrical charge characteristics;
5. The microsphere material must be both biologically and antigenically inert, permitting eventual transfer to living mice and causing no reactions itself for up to two months;
6. The specific gravity of the finished microspheres must be in the range 1.002 to 1.012; and
7. The microspheres must be dispersable initially throughout the physiological culture medium containing the leukocytes in order to give the specific antibody-carrying leukocytes of interest an opportunity for surface immunoadherence.

Solid glass beads have many of the properties above except for their specific gravity of about 2.20; if uniform hollow glass spheres were available with the desired specific gravity, they might solve the problem. The discussion has assumed that specific gravity will form the basis of the separation but other possibilities might exist. While physical size might be a possibility, preliminary attempts to separate rosettes from background leukocytes by using Millipore filters have not been promising.

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[3] Useful general material on molecular aspects of antigens and on chemical immunology is given by M. Sela, Science, 166, 1365 (12 Dec. 1969) and by E. A. Kabat, Structural Concepts in Immunology and Immunochemistry (Holt, Rinehart and Winston, New York, 1968).

P R O B L E M S T A T E M E N T

"Noise Reduction in Laminar Flow Rooms"

What is Needed

Noise abatement methods and low noise fans are required for laminar flow rooms used for patient isolation.

Background

The National Cancer Institute is conducting a vigorous program to find the causes and cure for cancer, a major cause of death in this country. One of the approaches used is chemotherapy, or the use of drugs to cause remission of existing cancers. Patients requiring this treatment are usually weak and more susceptible to other diseases than normal patients. A sterile environment would help to combat this problem as well as increasing the patient tolerance to antitumor drugs with regard to incidence of infection. A sterile environment can be produced by a laminar flow room which is equipped with sterilizing agents in the filter system.

The existing laminar flow rooms were designed to be installed inside standard hospital rooms, which allows maximum flexibility in the use of these rooms. This design, however, requires that the blower fans be inside the patient's room, which creates a noise problem. A heating and air conditioning consulting engineering firm has added conventional noise abatement procedures such as foam padding in ducts, a discharge muffler, and vibration isolators on the motors. However, even with these additions, the resulting noise level is intolerable.

Requirements and Specifications

The existing noise level is shown in the attached graph.

Noise abatement procedures are desired which will reduce the noise level from the existing Noise Criterion 50 to Noise Criterion 30. Noise Criterion 30 is defined as approximately 50 decibels at 100 Hz and 26 decibels at 10,000 Hz. The decibels are relative to 0.0002 dynes/cm^2. The air velocity output varies between 30 ft/min. and 90 ft/min. and the blower capacity is 2,000 cu. ft/min. at a static head of one inch of water. A centrifugal fan is used, and a fan which produces lower noise levels is desired.

Characteristics of Relevant Technology

(Note: This section is illustrative only, and is not intended to bias other avenues of approach.)

One possible approach would be to reduce the noise by design of rotor blades that would not produce as high a noise level as presently exists.

References

A computerized literature search of NASA's aerospace information bank has been performed, and the below-listed references were identified which appear to be applicable to the problem. However, many relevant references may not have been identified by this means, and any additional suggestions will be appreciated.

1. N69-21730 - "Characteristics of Noise Generated by Ducted Propellers and Fans," by D. H. Hickey.
2. N69-11546 - "Duct-Lining Materials," by R. A. Manearotty, Alan H. Marsh, and E. Feder.
3. N65-28547 - "Decreasing the Noise Level of Centrifugal Fans," by G. Khoroshev and Y. I. Petrov.

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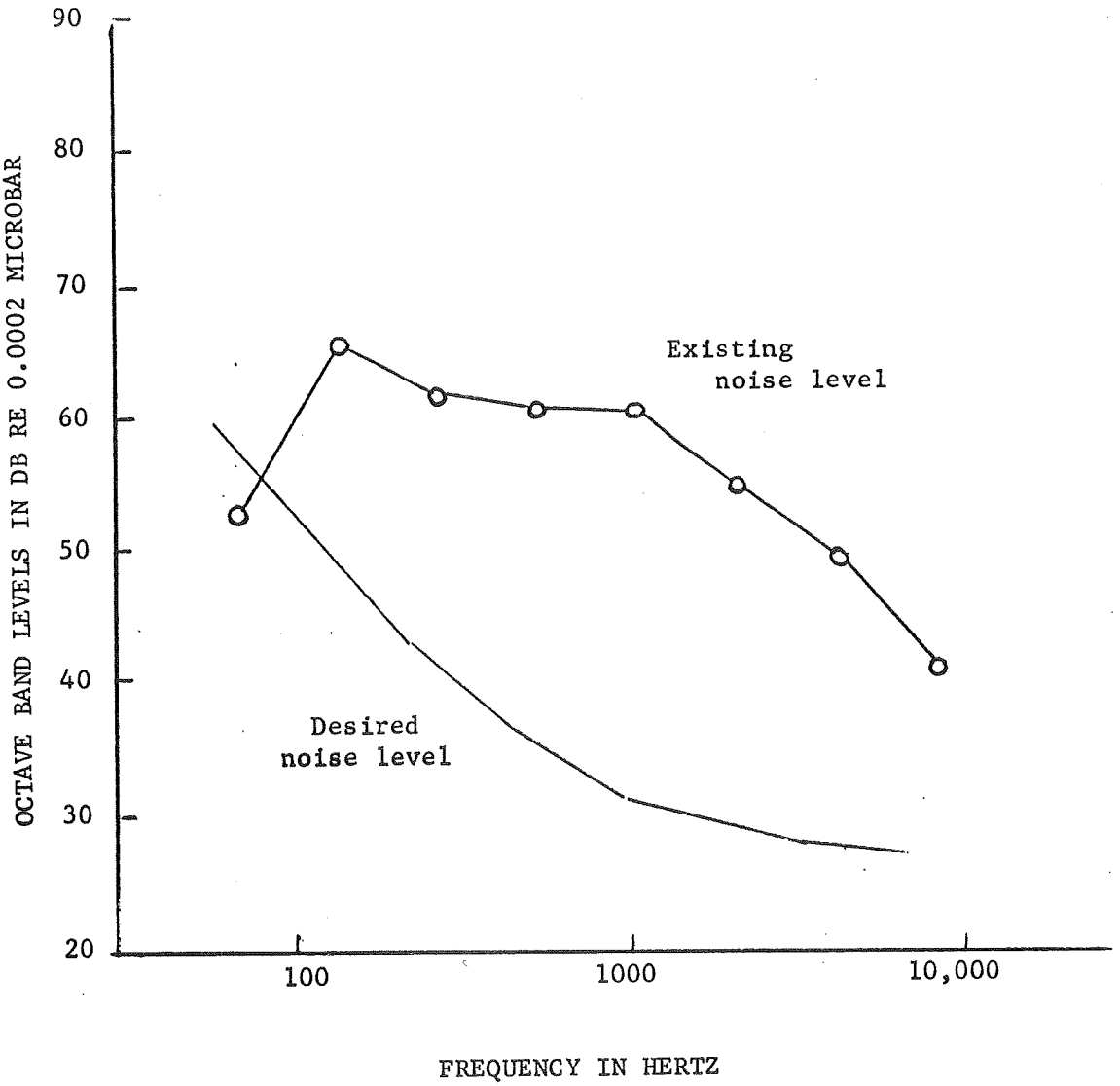
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OCTAVE BAND LEVELS IN DB RE 0.0002 MICROBAR
Existing
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Desired
noise level
100
1000
10,000
FREQUENCY IN HERTZ

RTI/NCI-2
October 1969

P R O B L E M S T A T E M E N T

"Lactate/Pyruvate Measurement in Blood"

What is Needed

A rapid method of measuring the lactate or pyruvate concentration in the blood is required.

Background

Leukemia, a major cause of death, is a disease which is characterized by an unusually high number of white blood cells. Many forms of the disease exist, but nearly all forms have a rapid onset of symptoms.

The National Cancer Institute is conducting a vigorous program to find the causes and cures for this disease. In the clinical phase of this program, a problem exists in the prevention of shock. If not detected early enough, shock can cause serious infection which is a major problem in leukemia patients. Thus, a need exists for an accurate indicator of the onset of shock so that corrective measures can be taken.

One measure of the onset of shock is the pyruvate or the lactate concentration in the blood. Both lactate and pyruvate and intermediate products in the metabolism of carbohydrates and proteins. The concentration of lactate and pyruvate in the blood is a measure of the oxygen availability to the tissue.

Existing methods for measurement of these organic compounds are inadequate because of the long analysis times required. The usual wet chemistry method has been replaced in the last few years by an enzymatic method but a time of 45 minutes is still required which is inadequate.

Requirements and Specifications

A method is required which allows measurements within 5-10 minutes but preferably an on-line system. Normal procedures involve taking 5 ml blood with lactate levels of 9-15 mg% and pyruvate levels of 0.39-0.86 mg%.

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P R O B L E M S T A T E M E N T

"Blood Pressure Measurement"

What is Needed

A new method of measuring blood pressure is required.

Background

Leukemia, a major cause of death, is a disease which is characterized by an unusually high number of white blood cells. Many forms of the disease exist, but nearly all forms have a rapid onset of symptoms.

The National Cancer Institute is conducting a vigorous program to find the causes and cures for this disease. In the clinical phase of this problem, a problem exists in the prevention of shock. If not detected early enough, shock can cause serious infection which is a major problem in leukemia patients. Thus, a need exists for an accurate indicator of the onset of shock so that corrective measures can be taken.

One important measure of the onset of shock is a reduction in blood pressure. Blood pressure is defined as the pressure exerted by the blood within the arteries. The two pressures of interest, systolic and diastolic, are the maximum and minimum pressures exerted by the pulsatile pumping of the heart.

The primary method for measuring blood pressure is the sphygmomanometer which is a cuff placed around the upper arm. The microphone end of the stethoscope is placed under the cuff and over the brachial artery near the fold of the arm. The cuff is inflated to a pressure which is higher than blood pressure and is then slowly reduced. When the cuff pressure reaches the systolic pressure, a pulse is heard in the stethoscope. When the cuff pressure is reduced still further to the diastolic pressure, the pulse sounds drop sharply.

The cuff method is unsuitable for continuous monitoring of blood pressure because of the need for repeated inflation of the cuff which disturbs a patient.

Requirements and Specifications

A method of monitoring blood pressure on a continuous basis is required for bed patients. The method should not significantly disturb the patient. The pressure range of interest is 0-2000 mm Hg and a sensitivity of from 5-10 mm Hg is required. An invasive technique (i.e., one which punctures the skin) is considered undesirable.

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P R O B L E M S T A T E M E N T

"Controlled Rate of Freezing A Liquid"

What is Needed

A method is required for detecting the onset of freezing of white cells and then increasing the heat transfer rate during the release of latent heat so that a nearly constant freezing rate can be maintained.

Background

Leukemia, a disease which kills about 15,000 Americans annually, is characterized by a proliferation of the tissue which forms white blood cells. Although the white cells in the blood can either increase, decrease, or remain constant in number, the bone marrow where the cells are formed will proliferate.

Treatment of leukemia involves killing the cancerous white blood cells in the blood and in the bone marrow using drugs or radiation. This process can cause loss of all bone marrow so that normal white cell production cannot occur.

When this loss of bone marrow occurs, white cells must be resupplied to the patient. For this purpose a bank or storage facility of white cells is required. This is impossible at present because adequate storage procedures are unavailable. Although red cells can be preserved by freezing, white cells are now destroyed by the existing freezing and thawing procedures. One important parameter in freezing white cells is believed to be the rate of freezing. Rate of freezing cannot at present be controlled because of the plateau in cooling rate when the latent heat is released at the freezing point.

The present method for freezing is a liquid nitrogen system which cools a secondary liquid which in turn cools the cells contained in a flat Teflon bag. To prevent contamination of the cells, it is desirable that any new technique utilize a Teflon container.

The basic requirement is to have a method of detecting the onset of freezing and then increasing the heat transfer rate during the release of latent heat so that a nearly constant rate of freezing can be maintained from room temperature to -50°C.

Requirements and Specifications

The unit should be capable of freezing 100 milliliters of white cells at a constant rate which can be varied from 1 to 10°C/min. The thermodynamic properties of white cells are not known but a good approximation is that they are similar to water. The freezing point, the only parameter well known, varies from -5°C to -20°C depending on the particular sample.

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P R O B L E M S T A T E M E N T

"Separation of White Cells"

What is Needed

A method of separating white cells of human blood as a function of size or density is required.

Background

Leukemia, a disease which kills about 15,000 Americans annually, is characterized by a proliferation of white blood cell forming tissue. Efforts to find the cause and cure of this disease are important, not only because of the disease death rate, but because the disease is the only form of cancer that can be continuously studied (i.e., repeated blood samples can be taken but repeated samples of solid tumors cannot). Thus, understanding leukemia will provide a vital key to understanding cancer.

Part of the difficulty in understanding leukemia is the fact that a poor understanding exists of the role of the various blood constituents as well as the constituents of the blood-forming organs. These constituents are cells which can be considered to be spheres with about 10-20 microns diameter. The cells are all very similar in specific gravity (1.06 to 1.08).

A method is required of separating the cells according to size or density such that an undamaged quantity of each category of cells is retained. The existing methods for this separation include sedimentation and centrifuging. Sedimentation consists of allowing the cells to settle in a viscous medium contained in a one-foot deep tank. This technique produces an insufficient number of cells. Centrifuging methods now existing do not allow sufficiently fine separation of cells.

A new separation method or an improved centrifuging method is required.

Detailed Background

Blood consists of red cells, white cells, platelets, and plasma. Two methods for studying these elements exist, and they are (1) examining the whole blood sample under a microscope, and (2) separating the blood into four elements by centrifuging or sedimentation. The first method is useful for obtaining populations of the blood, but the second method must be used when undamaged samples of blood elements are desired. The second method, centrifuging or sedimentation, can allow separation of the blood into the four components: red cells, white cells, platelets, and plasma. In addition, filter techniques can allow further separation of white cells into three categories (monocytes, lymphocytes, and granulocytes). Unfortunately, granulocytes and monocytes are destroyed using this approach leaving only the lymphocytes. One part of this problem is to separate these three categories of white cells without destroying the cells.

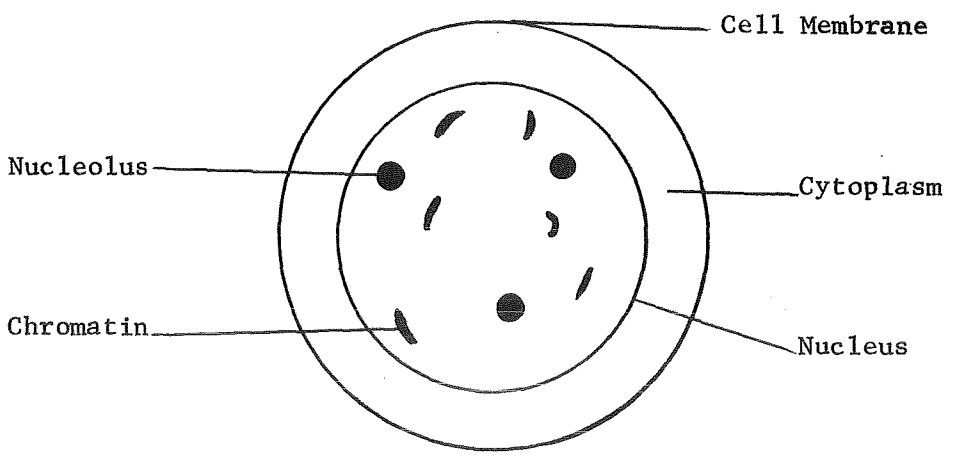
The functions of granulocytes are not completely known, but it is known that they ingest bacteria and thus are used in fighting infection. Granulocytes originate in the bone marrow but later pass into the blood stream. Another part of this problem is to separate the granulocyte into the various stages of maturity. Granulocytes originate as myeloblasts and progress in a continuous manner to the final form. However, definite stages of the transformation are recognized and categorized. The categories are as follows: myeloblast, promyelocyte, myelocyte, metamyelocyte, granulocyte. The differences in these categories are listed in the attached table, although certain generalizations can be made about the cells as they approach maturity. These differentiations are as follows:

Cytoplasmic
Loss of basophillia - Immature cells are deeply basophillic, (i.e., stained by basic dye). This is lost with maturity.
Granules - Immature cells have only a few and they are red. Number increases and one type of granule [basophillic, eosinophillic (stained by acid dye), neutrophillic, (stained by neutral dye)] will predominate in maturity.

Nuclear
Cytochemistry - Immature nucleus is round or oval with high nucleus cytoplasm ratio. Reduction in number of nucleoli occur. Mature cells may have no nucleoli.
Shape - Nucleus becomes lobed. Of two young cells, the older is the one showing more deviation from oval nucleus.

Cell Size
Mature cell becomes smaller. Also nuclear condensation is greater which means mature cell has smaller relative nucleus.

Thus the second part of the problem is to separate a sample of granulocytes into the various categories which represent various stages of maturity.



Requirements and Specifications

The method should allow collection of about 0.1 cubic centimeter of each category of cells. If the cells are categorized by size, each category should include a one-micron range (e.g., 10 to 11, 11 to 12, 12 to 13, etc.). If the cells are categorized by specific gravity, each category should include a specific gravity range of 0.002 (e.g., 1.062, 1.062 to 1.064, etc.)

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Summary of the characteristics of some blood and bone marrow cells

Cell	Size (μ)	Nucleus	Nucleoli	Cytoplasm	N/C ratio	Comments
Myeloblast	10-20	Large, oval or round; thin membrane; stippled or finely reticulated chromatin; sparse, sharply demarcated parachromatin	2-5,distinct	Sparse no granules deeply basophilic	7:1	Usually does not show clear perinuclear halo as in lymphoblast, nor is chromatin as coarse as in lymphoblast nucleus; in pathologic proliferation these cells may be very large (macromyeloblasts) or about the size of young lymphocytes (micromyeloblasts); latter easily mistaken for lymphocytes, but micromyeloblast contains finer chromatin.
Promyelocyte	14-20	Large,round or oval; thin membrane; chromatin netlike with some clumping next to nucleoli; parachromatin sparse	1-3, not as prominent	Sparse, basophilic but not as intense as in myeloblast	5:1	Distinguished from myeloblast chiefly by presence of granules and from later cells by small number of granules; at times granules large and round, but usually fine and irregular
Myelocyte a.Neutrophilic b.Eosinophilic c.Basophilic	10-18	Indistinct when cell heavily granulated; chromatin fairly coarse; parachromatin sparse	0-1, indistinct	Moderate, heavily granulated; granules may obscure nucleus	2:1	Most heavily granulated of blood cells; granules may be purplish at early stage of development, later differentiate into basophilic,eosinophilic, or neutrophilic
Metamyelocyte a.Neutrophilic b.Eosinophilic c.Basophilic	10-18	Kidney-shaped, heavy nuclear membrane; chromatin coarse; parachromatin sparse	0	Fairly abundant,pinkish; contains specific granules smaller and more variable in size than in myelocyte	1.5:1	Indentation of nucleus indicates greater maturity; granules of neutrophilic metamyelocytes vary in size; in eosinophilic or basophilic cells granules remain large and usually obscure nuclear outline

Cell	Size (μ)	Nucleus	Nucleoli	Cytoplasm	N/C ratio	Comments
Band granulocyte a.Neutrophilic b.Eosinophilic c.Basophilic	10-15	Sausage or band-shaped; coarse, deeply staining purple chromatin; para-chromatin very scanty	0	Abundant, pinkish; contains specific granules, fine when neutrophilic	1:2	Nucleus may be constricted at one or more points but as long as there is visible chromatin between nuclear membranes cell called band form; when nucleus folded but constriction not visible should be classified as a band form; nuclear outline in basophilic and eosinophilic cells usually obscured by granules
Granulocyte a.Neutrophilic b.Eosinophilic c.Basophilic	10-15	Lobules of dense chromatin connected by one or more thin filaments	0	Abundant, pinkish; contains specific granules	3:1	Presence of one or more thin filaments identifies cell as segmented granulocyte; neutrophilic granules very fine, while eosinphilic and basophilic granules large and round, obscuring the nucleus
Lymphocyte	6-18	Round or oval, slightly or deeply indented;chromatin in coarse clumps	0	Sky blue or medium blue,clear and glassy	5:1-2:1	Vary in size, chiefly due to variation in amount of cytoplasm;sky-blue clear cytoplasm characteristic
Monocyte	12-18	Indented or folded, delicate,pale staining	0	Gray or gray blue, opaque; contains very fine pink granules	4:1	One helpful feature is that monocytic nucleus stains much lighter than similar cells

P R O B L E M S T A T E M E N T

"Method of Fast Warming of a Frozen Liquid"

What is Needed

A method is required for the fast warming of frozen white blood cells.

Background

Leukemia, a disease which kills about 15,000 Americans annually, is characterized by a proliferation of the tissue which forms white blood cells. Treatment of leukemia involves killing the cancerous white blood cells in the blood and in the bone marrow so that normal white cell production cannot occur.

When this loss of bone marrow occurs, white cells must be resupplied to the patient from a bank or storage facility of white cells. This is impossible at present because adequate storage procedures are unavailable. One part of the storage problem is a controlled freezing method which is the subject of problem number RTI/NCI-4, "Method of Controlled Rate of Cooling in Liquids." The second part of the storage problem is the warming or thawing of the frozen white blood cells which is the subject of this problem statement.

One important parameter in the successful warming of cells is believed to be the rate of temperature change. Researchers believe this because experiments with spleen cells have indicated that very fast warming rates can significantly increase the yield or survival rate of frozen cells.

The present method for warming cells is an infrared heating system for the cells contained in a flat Teflon bag. (To prevent contamination of the cells, it is desirable that any new technique allow the use of a Teflon container.) This infrared system is unsuitable because the cells are not warmed uniformly nor fast enough.

Because of the high rate of thermal energy transfer required, it is unlikely that any system utilizing conduction as the major mode of heat transfer will be sufficient. A system using radiant heating or microwave heating appears to be the most likely useful approach.

Requirements and Specifications

The basic requirement is to have a method of rapidly and uniformly warming a volume of frozen liquid from -150°C to room temperature. The method should be capable of warming a 20-milliliter volume of cells from -150°C to room temperature in one minute. The thermodynamic properties of white cells are not known, but a good approximation is that they are similar to water.

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APPENDIX D

Problem Statements Prepared During

Period September 1969 to March 1970.

Problem Statements Prepared During Period

September 1969 to March 1970

This appendix contains Problem Statements for all problems accepted during the reporting period with the exceptions of NCI-8, IRM-25, and MISC-3 which have not been prepared and with the exceptions of DU-48, DU-61, DU-67, NCI-1, NCI-2, NCI-3, NCI-4, NCI-6, and NCI-7 which were circulated to NASA Field Centers and are presented in Appendix C.

P R O B L E M S T A T E M E N T

"Determination of the Site of Bleeding in the Intestine"

What is Needed

A means is desired to determine the local site at which bleeding in the intestine is occurring, when evidence of such bleeding is established.

Background

The detection of bleeding in the gastrointestinal (GI) tract can be accomplished by analysis of the stool, provided the rate of bleeding is sufficiently high. Location of the exact point in the gastrointestinal tract from which the blood is issuing, however, is a much more difficult task. This problem is primarily concerned with identification and localization of the bleeding site so that corrective measures can be implemented. One technique which has been employed is to inject a contrast material into the blood circulation and take an X-ray of the gastrointestinal tract. This method requires biplane X-ray photographs for localization and, further, is useful only in cases where severe bleeding occurs.

Various researchers have investigated techniques for monitoring blood flow in the GI tract. One method* which has been used with some success in detecting impaired intestinal blood flow employs miniature Geiger Muller tubes to monitor radioactivity after intravenous administration of radioactive K^{42}.

Requirements and Specifications

There are two approaches which could be used if a radioactive indicator is chosen as the means of localization of the site of bleeding. First, a detector capable of registering the counts from the site where the bleeding occurs can be attached to a cord or tubing, and the detector position can be localized by X-ray procedures. Second, a free-ranging telemetering capsule can be swallowed. In this case, a means of localization of the capsule is also required. The problem, therefore, consists of two parts: (1) detection of blood in the gastrointestinal tract and (2) localization of the site from which blood is issuing. Localization of the bleeding site is desired to within one centimeter.

*Klaus J. H. Meckeler, Sidney J. Malawer, and Benjamin T. Jackson, "A Method For Detecting Impaired Local Blood Flow in the Intact Intestine," Gastroenterology, V. 52, No. 1, Jan. 1967, pp. 42-49.

While the illustrative material in this problem statement primarily describes an approach using radioactive indicator in the blood, other detection and localization methods may be superior. Consequently, such suggestions are encouraged.

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P R O B L E M S T A T E M E N T

"Assay of Amino Acids in Brain Tissue"

What is Needed

Improved methods of measuring amino acid concentration in the brain are needed.

Background

The normal human body metabolizes the chemical compounds required for normal growth and development of all tissues, including the brain. On occasion, however, the metabolic process is upset so that chemical reactions occur to produce abnormal compounds or abnormal amounts of normal compounds. These deviations in body chemistry appear in the blood and the tissues, and are frequently excreted in the urine. Detection of an abnormal compound, or assay of a normal compound in abnormal amounts, is the primary means whereby these metabolic errors are diagnosed.

The importance of the study of amino acid metabolism is underscored by the fact that a number of diseases causing mental retardation are known to be related to deviations in amino acid metabolism. It is thought by researchers that many diseases which have not been differentiated from the larger group of hereditable causes of mental retardation will eventually be correlated with abnormalities in a single amino acid.

One of the known metabolic errors associated with mental retardation is phenylketonuria. In phenylketonuria, an enzyme in the liver, phenylalanine hydroxylase, is present in reduced amounts. Normally, phenylalanine hydroxylase converts the amino acid, phenylalanine, to tyrosine. As a result, the absence of the enzyme phenylalanine hydroxylase causes the amino acid phenylalanine to be metabolized in an alternative fashion. This alternate metabolic process produces products not normally found in the blood or urine, i.e., phenylpyruvic acid, phenylacetic acid, O-hydroxyphenylacetic acid, phenylacetylglutamine, and possibly other compounds.

Children with this disease do not develop normally. They do not hold up their heads, sit, walk,or talk in the normal time. Their growth rates are lower than normal, and they have defective muscle tone. Other symptoms exhibited include abnormal behavior, muscle hypertonicity, decreased tendon reflexes, hyperkinesis, tremors, and seizures. The brain damage can be severe enough that spastic diplegia (spastic paralysis of the legs) also occurs.

Other diseases in which amino acid imbalance is observed are (1) Hartnup disease, (2) branched-chain ketoaciduria or maple syrup disease, (3) Histidinemia, (4) Glycinuria, (5) Cystathionuria, (6) Argininosuccinic aciduria, (7) Citrullinuria, (8) Hyperammonemia, (9) DOPA-uria, (10) Lowe's syndrome, and (11) Homocystinuria.

Significant research is being expended for the care and treatment of mentally retarded children. Great improvements have been and are being made in care and treatment of these patients. Prevention of mental retardation must, however, come from the information generated in biochemical research.

One interesting facet of the study of amino acid metabolism is that the amino acid concentration varies within the body. Specifically, the amino acid concentration in the brain is greater than the concentration of amino acids in the blood plasma, which is the source of amino acids for the brain tissue. Consequently, assimilation of amino acids from the blood plasma by the brain tissue must be accomplished against the concentration gradient. This difference in amino acid concentration has been attributed to a "blood-brain barrier." The researcher is seeking to characterize the transport of amino acids across this "blood-brain barrier". The study is a basic investigation into the nature and operation of the "blood-brain barrier" from a biochemical standpoint. Little is now known about the "blood-brain barrier", and it represents a gap in fundamental knowledge.

In order to study this phenomenon more precisely, improved methods for assaying amino acids are desired. The researcher is aware of currently employed clinical techniques and poses this problem to ascertain if more sensitive, more accurate, or more easily performed techniques amenable to this problem have been developed in the aerospace program.

Requirements and Specifications

Assay of amino acids is a difficult chemical process. To perform the amino acid measurement required by the researcher requires a significant amount of time. The researcher is interested in obtaining improved techniques for assaying the concentration of amino acids in the brain.

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P R O B L E M S T A T E M E N T

"High Frequency Pressure Transducers"

What is Needed

A pressure transducer is required with a frequency response higher that that of commercially available biomedical pressure transducers.

Background

The researcher is involved in an investigation of the volume elasticity of arterial vessels. The volume elasticity of arterial vessels is an important parameter required in cardiovascular system modeling and simulation studies. To determine the volume elasticity of a particular vessel, the vessel is filled with a fluid and subjected to pressure pulses generated by a piston. The change in pressure and volume are noted. The volume elasticity is calculated from the volume-pressure measurements thus obtained. The pressure pulses have components as high as 200 hertz, but conventional biomedical pressure transducers which the researcher is using have frequency responses of less than 100 hertz. A small pressure transducer with adequate frequency response is desired.

Requirements and Specifications

The transducer should have a frequency response in excess of 200 hertz, and preferably to 1,000 hertz. The pressure range desired is 0-5 pounds per square inch. The transducer must be mounted in a catheter with a diameter less than 3/16 inches.

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P R O B L E M S T A T E M E N T

"A Means of Measuring Evaporative Heat Loss from the Skin"

What is Needed

A method or technique is needed to measure the heat loss from the surface of skin as a result of evaporation of perspiration.

Background

The researcher is engaged in a project to determine the effectiveness of blood flow in the digits of humans. Disease can cause constriction of blood vessels in the tissue. Constriction impairs the irrigation of the tissues with blood, and if the impairment is sufficiently severe, the tissue becomes necrotic, gangrene follows, and amputation of the affected digits is required. In order to assess the blood flow to a digit, use can be made of the fact that the amount of heat supplied to the digit is proportional to the blood flow. Part of the heat delivered to the digit is lost by radiation. Part of the heat is lost by the evaporation of water vapor from the skin. Finally, part of the heat is shunted back to the body by the veins.

The temperature of the skin can be easily determined, and the radiated heat loss easily calculated. A means of determining the heat loss from the digit as a result of evaporation of water (perspiration) is desired.

Requirements and Specifications

The solution should permit determination of the evaporative heat loss to an accuracy of $\pm$ 5 percent. Ambient humidity and temperature can be controlled, and all measurements will be taken under near equilibrium conditions so that fast response time is not necessary. A response time of 30 seconds is adequate. Ideally, the measuring device should be small enough to permit measuring the evaporative loss from a single digit, i.e., one finger.

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P R O B L E M S T A T E M E N T

"Computer Processing of Chromosome Data"

What is Needed

Methods of computer processing of chromosome data to be used in detection of mongolism in fetuses are desired.

Background

The researcher, a geneticist, is engaged in a research program to permit the detection of mongolism in unborn fetuses sufficiently early to permit theraputic abortion. Techniques for accomplishing this determination are available; indeed, they are no more difficult than determining the sex of the fetus. However, they require the sampling of large numbers of blood cells, so that the process is not amenable to mass screening.

The greatest benefits can be derived from this technique only if it can be applied to the entire pregnant female population. For example, 150 mongoloids are born in North Carolina each year. The cost during the mongoloid's lifetime to the state is between $50,000 and $100,000. If this test could be applied to the entire pregnant female population of the State of North Carolina, there would accrue a saving of approximately $11,000,000 each year. Mongolian idiocy is the major single cause of severe mental deficiency, and the elimination of mongoloids would result in a 10 percent reduction in the number of people in state mental institutions. The national saving could be extrapolated by considering that approximately 6,000 mongoloids are born nationally.

As presently accomplished, a technician examines blood cells from the maternal blood. In order to obtain enough fetal blood cells to be statistically adequate, the technician must examine approximately 1200 cells. First, the white cells are examined and the positions of those that are dividing are noted, using a projection attachment to the microscope. The total number is obtained. Then it is necessary to go back and look at each cell in detail under higher magnification. Under high magnification, the chromosomes of each cell are classified.[1,2] Some of the chromosome

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[1] J. A. Serra, Modern Genetics, Vol. 3, 1968, Academic Press, London, pp. 199-205, p. 242.

[2] Human Chromosome Methodology, Edited by Jorge J. Yunis, 1965, Academic Press, N. Y. and London; Chap. "Identification of Chromosomes," Klaus Patau, pp. 155-186; and Chap. "Human Chromosomes in Disease," J. J. Yunis, pp. 187-242.

types are abnormal types, and the presence of specific abnormal types permit correlation with particular disease anomalies. There is a particular chromosomal aberration associated with mongolism. A normal person has 46 chromosomes which consist of two each of 22 types plus X and Y sex chromosomes. Mongoloids have an extra type 21 or type 22 chromosome or part of a chromosome. There are two types: (Note in the following examples, 21 can be read as either type 21 or type 22 chromosomes.)

(1) Triplo-21, in which the individual has 47 chromosomes with three, instead of two, type 21 chromosomes.
(2) Translocation mongolism, in which the extra 21 type chromosome has become attached to one of the chromosomes not associated with the sex of the individual. Generally, the extra 21 type becomes attached to one of the type 15 chromosomes, so that the individual has 46 chromosomes. In this case there are two normal type 21 chromosomes, but only one normal type 15 chromosome. The abnormal chromosome is the joined 15-21 chromosome.

Another important factor in mongolism is that the incidence of mongolism increases with the age of the mother. For example, a woman of 20 has one chance in 3,000 of producing a mongoloid, while a woman of 45 has one chance in 40.

This karotyping (chromosome classification) must be done on the fetal blood cells. Fetal blood cells are present in very small concentrations in the maternal blood. Blood samples are taken from the mother, hence the majority of blood cells thus obtianed are maternal cells.

Two approaches can be taken to reduce the time required in karotype blood for detecting mongolism. First, a means of processing the blood sample so as to enrich the number of fetal cells with respect to maternal cells would significantly reduce the screening time. One phase of the researcher's program is aimed at this aspect of the problem.

Second, data processing techniques can be applied to the problem to speed up the screening process. There are two levels at which computer processing could be used to advantage:

(1) The computer can be used to store the data, to note position of the individual cells, and to assess the cells on the microscope slide for karotyping with visual discrimination and classification being performed by the technician.
(2) By employing digital image processing and pattern recognition techniques, the computer can be made to perform the karotyping as well as the data processing.

If the karotyping is performed by means of computer, a scanner of some type is required. In addition, a more sophisticated computer is required than the computer that would be needed to perform the first option. Because of the equipment cost and complexity, it is expected that the first option will be exercised with potential expansion of the system to permit automatic computer karotyping for mongolian idiocy.

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P R O B L E M S T A T E M E N T

"A Miniature Infusion Pump"

What is Needed

A miniature pump is needed to infuse drugs into a patient over a 24-hour period.

Background

In some inoperable cancer cases, it is desirable to perfuse with drugs the area in which the tumor is located. This is done by inserting a hypodermic needle (connected to the pump) into an artery which perfuses the area surrounding the tumor. These patients are usually sent home from the hospital since little can be done for them. Consequently, since the infusion pump is worn by the patient, it must be portable and have its own power source.

Requirements and Specifications

The infusion pump must administer medication at a rate of 2-8 cubic centimeters of medication per 24-hour period. The power source must also permit operation for 24 hours without an external supply of energy. The pump should be simple to recharge with medication, and the power source must be easily renewed or replaced. Size should be small enough to permit wearing of the pump and power source continuously. A volume of 10 cubic inches and a weight of one-half pound are good general indicators. Finally, cost is a consideration since the cost of operating the unit and amortization of its initial cost must be met by the patients being treated.

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P R O B L E M S T A T E M E N T

"A Means of Detecting Turbulence
in Blood Flowing in a Tube"

What is Needed

A method of determining whether blood flow in a tube is laminar or turbulent is required.

Background

The indicator concentration method is one technique used to compute mean flow through and the volume of blood contained in a portion of the vascular system. Much theoretical and experimental work has been done in this area. Researchers at Bowman Gray School of Medicine, Wake Forest University, are engaged in an experimental program to accurately define these types of measurements. Because of the complexity of biological systems, initial studies have been made using a model in which an indicator (dye or radioactive) is injected mechanically at a constant rate into a uniformly flowing stream of blood in a plastic tube of uniform diameter. The time of injection can be varied in order to control the amount of dye injected. The injection rate is 0.01 cubic centimeters of indicator per second. The injection time can be varied from one-tenth second to about 10 seconds. The range of volumetric flow of the fluid in the tube is between 2.5 and 25 cubic centimeters/minute (flow velocity of 0.3 cubic centimeters/second to 3 cubic centimeters/second). Downstream from the site of injection is a counter or photocell, depending upon the type of indicator used, whose output is recorded on a strip chart. The output of the detector is proportional to the concentration of the dye or radioactive substances in the stream. Under experimental conditions, flow is maintained laminar or streamlined. Laminar flow causes much higher velocities near the center of a tube so that the actual injection point in a tube cross section is critical.

To overcome this problem in the model system, a rotary, magnetically operated mixer is installed immediately upstream from the injection site. This mixer induces turbulence, breaking up the laminar flow so that, in the region of the injection site, the fluid flow is turbulent. Therefore, the velocity is approximately uniform across the entire diameter of the tube just below the mixer. Laminar flow is soon restored in the tube. If one considers equal quantities of indicator which are traveling at different speeds, it is easily seen that the slower moving fluid will remain for a longer period of time under the counter aperture, therefore producing more counts than the rapidly moving indicator. This means that the indicator concentration is biased so that equal concentration and lengths of laminar of indicator fluid

do not produce the same number of counts; i.e., a fixed volume and a fixed concentration of indicator fluid moving at a higher rate produces fewer counts than the same volume and the same concentration of indicator moving at a lower rate.

To overcome this measurement difficulty, a mixer has been placed in the experimental apparatus upstream from the sampling site. This produces turbulence, thoroughly mixing the indicator components which were traveling at different velocities in the laminar flow region, so that the velocity of all the indicator is approximately the same as it passes under the counter aperture. Without the use of mixers to produce turbulence at both the injection and the sampling sites, it has not been possible to obtain reliable data on blood rate of flow and volume.

Design of the mixers has been a difficult problem. Small, motor-driven variable-speed propellers are currently used to mix the dye. To achieve proper mixing, it is extremely important that the mixers induce turbulence. With the present experimental arrangement the researchers have no means of sensing whether the mixers are actually inducing turbulence. An appropriate sensor which can detect the onset of turbulence is required.

Requirements and Specifications

The sensor must permit detection of turbulence (onset of turbulence) in blood flowing in a glass or plastic tube approximately four millimeters in diameter. Physical size of the sensing element inserted into the blood stream should not have a cross section greater than 1.0-1.5 square millimeters. Insertion of the sensing element must be accomplished without allowing the escape of blood from the tube. It must operate with flow velocities in the range of 0.3 centimeters/second to 3.0 centimeters/second.

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P R O B L E M S T A T E M E N T

"Prevention of Tip Washout in Dye Injection Techniques"

What is Needed

A means of preventing "washout" of dye from the tip of a dye injector is desired.

Background

Researchers at Bowman Gray School of Medicine, Wake Forest University, have been engaged in an experimental program to accurately define the methods and techniques which can be used to obtain reliable data from these types of measurements. Because of the complexity of biological systems, initial studies have been made using a model in which an indicator (dye or radioactive) is injected mechanically at a constant rate into a uniformly flowing stream of blood in a plastic tube of uniform diameter. The time of injection can be varied in order to control the amount of dye injected. The injection rate is 0.01 cubic centimeters of indicator per second. The injection time can be varied from one-tenth second to about 10 seconds. The range of volumetric flow of the fluid in the tube is between 2.5 and 25 cubic centimeters/minute (flow velocity of 0.3 centimeters/second to 3 centimeters/second.) Downstream from the site of injection is a counter or photocell, depending upon the type of indicator used, whose output is recorded on a strip chart. The output of the detector is proportional to the concentration of the dye or radioactive substances in the stream. The dye injection method now in use consists of a hypodermic syringe which is driven by a step motor which can be set to inject the required amount of dye. The tip of the hypodermic needle protrudes into the flowing stream of blood. A problem associated with this technique is washout of dye from the needle tip.

For example, after a measured quantity of dye is injected into the stream, the needle itself remains full of dye. Capillary forces hold the dye in the needle. However, as a result of diffusion and differential pressures at the needle tip caused by the flowing stream, small quantities of dye continue to leak into the stream after the injection of dye has occurred. This trickle of dye into the stream after injection has ceased appears, as far as the detector is concerned, as slow-moving blood. Thus, this washout adds to the slow-moving blood and biases the plot of velocity versus dye concentration toward the low velocity side. When this curve is used to determine average flow velocity, the calculated average flow velocity is slower than the actual flow velocity because of this washout effect. A means of preventing washout is desired.

Requirements and Specifications

To be acceptable, the hardware employed to solve this problem must have the following characteristics. First, the injection device and washout prevention device must not exceed one millimeter in diameter. Second, it must be possible to move the injection point from one tube wall to the other across a diameter (total travel of approximately four millimeters). Finally, it would be desirable if the injection method imparted as little velocity as possible to the injected dye.

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P R O B L E M S T A T E M E N T

"Identification of Infrared Spectra Using Computer Techniques"

What is Needed

The researcher wishes to obtain FORTRAN-compatible computer programs for the storage and retrieval of infrared spectrographic data on selected chemical compounds.

Background

The Bowman Gray School of Medicine operates a computer center which performs various data processing functions for the Bowman Gray Hospital, the Medical School, and individual faculty and graduate student researchers. There are a number of researchers (biochemists, geneticists, pharmacologists) in the Medical School, as well as in the Physical Sciences department (chemists, physicists) of Wake Forest University who on some regular basis during their research find it necessary to use infrared absorption spectrum data as a means of identification of unknown compounds. Presently, the basic source of information on infrared spectral absorption data available to these researchers is the spectral absorption data card file available from American Society for Testing Materials. For compounds not in the ASTM data file, the researcher must perform standardized experiments to obtain reference data. This information is also put on reference cards in the researcher's data file. There are literally thousands of spectra on different compounds. Thus, if it becomes necessary to manually search the entire data file to identify the unknown, it is a very time-consuming and difficult task.

The researcher wishes to generate a reference library of infrared spectral data, store it on magnetic tape, and provide rapid "unknown" identification by computer searching the reference data file. This is not a new technique, in that such computer search systems have been developed previously.[1,2,3,4]. The researcher could, himself, develop the needed computer program, but a significant amount of time and money could be saved if an already developed, FORTRAN-compatible program to accomplish this could be obtained. Unfortunately, the researcher has not been able to locate a

1. R. A. Sparke, "Storage and Retrieval of Wyandotte-ASTM Infrared Spectral Data using an IBM 1401 Computer," ASTM, Philadelphia, Pa., 1964.
2. L. D. Smithson, L. B. Fall, F. D. Pitts, and F. W. Bauer, "Storage and Retrieval of Wyandotte-ASTM Infrared Spectral Data Using a 7090 Computer," Tech. Doc. Rept. # RTD-TDR-63-4265, Res. and Tech. Div., Wright-Patterson AFB, Ohio, 1964.
3. T. A. Entzminger and E. A. Diephaus, "Storage and Retrieval of Wyandotte-ASTM Infrared Spectral Data Using a Honeywell-400 Computer," U. S. Public Health Service, Robt. Taft Sanitary Engineering Center, Cincinnati, Ohio, 1964.
4. Sadtler Research Laboratories, 1517 Vine St., Philadelphia, Pa.

source for this program. He has contacted some of the organizations which have developed such programs, but has been unable to obtain them for various reasons, including communication difficulties and company confidentiality of the information.

Requirements and Specifications

The researcher wishes to obtain a program to build and store an infrared spectral absorption data file on magnetic tape and to identify unknown compounds by searching the data file. Organic compounds will comprise the majority of unknowns which are likely to be encountered. In most circumstances, the raw infrared spectrometer output data would be recorded on strip charts. The researcher would read the strip chart, determining the pertinent absorption peaks for the unknown. This information would be manually transferred to punched cards for comparison with the computer reference file. In other words, there is no requirement for online operation with the infrared spectrometer directly connected to the computer. A working debugged program that is FORTRAN-compatible is desired.

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RTI/WF-85
March 1970

P R O B L E M S T A T E M E N T

"Use of Computers in Planning Radiation Therapy"

What is Needed

FORTRAN-compatible computer programs to permit the rapid calculation of isodose contours for various radiation therapy treatment plans to speed the delivery and lower the cost of radiation therapy treatment.

Background

In radiation treatment, the radiation from external sources must be directed at a tumor so as to maximize the dose to the tumor while minimizing dose to surrounding tissue and avoiding, as much as possible, vital organs. This is accomplished by directing the beam of the radiation source(s) from different angles so that the tumor is situated at the intersection of these radiation beams and thus receives the additive effect of all the beam directions.

To carry out this procedure, the therapist must devise a plan of radiation therapy. The angles and doses are chosen based on a knowledge of the anatomy involved and the experience of the therapist. Efficacy of a particular treatment plan is given by the dose distribution. Hence, he must calculate isodose contours for the resulting treatment plan. If the dose to the tumor is adequate, and the dose to surrounding tissues is acceptable, he then implements the plan. If the dose to the tumor is inadequate or the dose to any of the surrounding tissue is too high, he must devise another treatment plan and calculate the isodose contours. This alteration of treatment plan and corresponding calculations is performed until an acceptable treatment plan is devised.

Using computer techniques, determination of the dose distribution for a given plan can be automated. With established mathematical relationships between dose intensity and geometry, computers can generate dose distributions for given treatment plans not only much more rapidly but also in much greater detail. Consequently, the radiologist can examine as many treatment plans as necessary, and then choose the plan which is optimized to suit the needs of the individual patient.

Requirements and Specifications

Already developed, FORTRAN-compatible computer programs for application to this problem are desired.

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P R O B L E M S T A T E M E N T

"Reduction of Anxiety by Noncontact Stimulation"

What is Needed

A means of reducing anxiety by noncontact stimulation is needed.

Background

In the practice of clinical psychiatry, it is necessary to put the patient at ease at the beginning of the session. The psychiatrist must devote several minutes to establishing rapport with the patient and essentially persuading the patient into a relaxed state of mind. It is necessary, as the session continues, that the psychiatrist delve successively further into areas that are emotionally charged for the patient. Indeed, these are the areas for which the session is held in the first place. In many patients, as soon as the conversation approaches the emotionally charged subjects, the patient exhibits extreme anxiety. He begins to hyperventilate and loses consciousness. In fact, this may be a deliberate escape mechanism with some patients to avoid discussion of the emotionally charged subjects.

In any event, the session must be interrupted while the patient is placed on a bed and allowed to regain consciousness. Then, the procedure must be started all over again. Obviously, this means that a significant amount of the psychiatrist's time, as well as the patient's time, is wasted. The investigator is interested in external means of rapidly reducing anxiety in these patients.

If a rapid external means of reestablishing a sense of calm or well-being in the patient could be applied when the psychiatrist detects the beginnings of anxiety in the patient, then the session could be salvaged, and a significant amount of time would be saved.

Requirements and Specifications

Since these patients are all emotionally disturbed, anything which would contribute to their anxiety must be avoided. Consequently, attachment to the patient by any means (wires, electrodes, etc.) must be avoided. Aural, photic, or other noncontact methods of reestablishing a sense of well-being in the patient is desired. To be effective in the saving of professional and patient time, the method should not require long exposure to induce calm. Patient response to the stimuli in five minutes is acceptable.

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P R O B L E M S T A T E M E N T

"Urine Flowmeter"

What is Needed

A requirement exists for a method of measuring temperature on the end of a small probe.

Background

Parkinson's Syndrome is a disease affecting a significant number of people and the principal features of the disease are coarse tremors involving the head and the limbs, slowness of movement, slow or shuffling walk, and loss of facial expression. One method for teating this disease is the production of lesions (injured regions) in the brain. Several methods of producing these lesions exist, one of which is the use of a small rf (radio frequency) field probe. In order to control the production of the lesion, good temperature measurement is required at the site of the lesion.

Two types of rf lesion probes are used. One type is an inflexible cylinder 0.080" x 12" and the other type is an inflexible cylinder 0.080" x 10" with a flexible cylindrical tip with dimensions 0.020" x 1". In the first type of probe, a small thermocouple is mounted on the tip of the probe. In the second type of probe the temperature of interest occurs at the end of the flexible 0.020" diameter tip. The tip is so small that the researcher has been unable to mount a thermocouple on the end.

The researcher requires a means of measuring temperature on the end of the flexible probe tip.

Requirements and Specifications

The temperature measurement should have a precision of $0.2^{o}C$ and an accuracy of $0.5^{o}C$. The temperature range is $30^{o}C$ to $50^{o}C$. The measurement method should not significantly enlarge the diameter of the flexible tip.

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P R O B L E M S T A T E M E N T

"Measurement of Single Nerve Cell Activity"

What is Needed

The "firing" of individual nerve cells must be detected and the detection technique should not require penetration of the cell wall.

Background

When a neuron (a nerve cell) is appropriately stimulated by another neuron, it "fires" and then returns to its initial state. "Firing," the conduction of an electrical pulse through the neuron membrane (neuron cell wall), is due to transient changes in the membrane's sodium and potassium ion conductivities. The connection between two neurons is called a synapse and has the property of transmitting information in one direction only. One neuron can be stimulated by more than one driving neuron and can stimulate multiple neurons.

In addition to the above excitatory action of one neuron on a following one, there is the possibility of an inhibitory effect of a neuron on another. These effects and the general electrophysiology of individual neurons are now reasonably well understood.[1,2] Viewing the brain as a highly complex computer and the neuron as the fundamental circuit element of that computer, the next step is the examination of the functional relationships of aggregates of interconnected neurons.

The researchers of the present problem are studying the functional organization of neural aggregates in the sea hare, Aplysia californica, a mullusk about ten inches long. In Aplysia, there is no central nervous system analogous to the brain and spinal cord of man. Instead, the functions of the system are carried out by several ganglia, characteristic aggregates of neurons, which are distributed in the animal. By determining neuron interactions within one ganglion, it may be possible to determine the "wiring diagram" for that specific "logic module" of the system. Knowledge gained in this research will contribute greatly to the understanding of the vastly more complex human central nervous system. The abdominal ganglion of Aplysia contains about 1500 neurons and of these at least 30 have been reproducibly identified. Already considerable progress has been made in studying interactions among these.[3]

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1. A good general introductory textbook is B. Katz, Nerve, Muscle and Synapse, McGraw-Hill, New York, 1966.
2. Proceedings of the IEEE, V. 56, No. 6 (June 1968) a special issue entitled "Studies of Neural Elements and Systems." In particular, the articles by J. W. Moore, "Specifications for Nerve Membrane Models," pp. 895-905, and by C. F. Stevens, "Synaptic Physiology," pp. 916-930.
3. E. R. Kandel and H. Wachtel, "The Functional Organization of Neural Aggregates in Aplysia," in Physiological and Biochemical Aspects of Nervous Integration, Francis D. Carlson, ed.,Prentice-Hall, Englewood Cliffs, N. J., 1968.

The present methods for determining the connections between different neurons use KCl-filled glass micropipette electrodes inserted through the cell wall into the interior of the neurons in question. As tip diameter is decreased to reduce trauma to the cell, the microelectrode impedance increases requiring high input impedance signal amplifiers.

The tip of the microelectrode is subject to clogging and erratic behavior, and its electrical properties are considerably more complex than a pure resistance.[4] The insertion of microelectrodes through the cell wall into the interior of the desired cells is a difficult and tedious process. An extracellular alternative to this technique would represent a significant breakthrough in the fundamental research on brain and nervous system organization.

Requirements and Specifications

The neurons of interest in Aplysia are of the order of 50-100 microns in diameter and their main cell body is roughly spherical. Whatever method is used must be able to distinguish one cell's action from another's. For instance, if an extracellular microelectrode were placed equidistant from two neurons, one could not tell which of the two contributed to observed electrical signals. It is probably necessary to achieve probe dimensions in the range of 10 microns or so. The cell's environment will be conductive (saline solution).

The peak change of voltage of the neuron interior relative to its exterior is around 100 millivolts and the total electrical current across the cell boundary may be in the range 0.1-1.0 microamperes; these values persist for times of the order of 10 milliseconds or less. The change in potential is produced by net conduction of sodium ions inward through the neuron membrane followed by conduction of potassium ions outward through the membrane. Typical concentrations of sodium are 460 millimoles (mM) per liter outside the neuron and 50 mM/l inside; corresponding potassium figures are 10 mM/l outside and 400 mM/l inside.

Among other effects, there may be changes in optical activity when a neuron fires. Keynes et al.[5] have been able to detect small fractional changes (around 10^{-5}) in light scattered at 90^{o} as a function of nerve activity. Also, extremely small quantities of heat are produced in nerve activity. While the researcher in the present problem wishes a method of recording a nerve action potential by techniques not involving the penetration of neuron membranes, any significant improvement in the conventional microelectrode techniques would also be of interest to him.

4. O. F. Schanne, M. Lavellee, R. Laprade, and S. Gagne, Proc. IEEE 56, 1072-1082 (June 1968).
5. L. B. Cohen, R. D. Keynes, and B. Hille, Nature 218, 438-441 (4 May 1968).

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P R O B L E M S T A T E M E N T

"Strain Measurements in Ligaments"

What is Needed

A measurement technique is needed to measure changes in length (up to 10% fractional changes) of ligaments in newly-amputated human knee joints.

Background

The knee is more complicated than a simple hinge joint, in that: (a) the axis about which flexion and extension take place is not a fixed one, but shifts forward during extension and toward the rear during flexion; and (b) the beginning of flexion and the end of extension are accompanied by rotary movements associated with fixations of the limb in a position of great stability. The bones involved in the knee are the femur (thighbone), the tibia (larger lower leg bone), and the fibula (smaller, outer bone of the lower leg, roughly parallel to the tibia).

Nearly a dozen ligaments (strong fibrous bands connecting at one end to bone and at the other to either another bone or to muscle) connect the bones of the knee joint. Of these, the cruciate ligaments are situated in the middle of the knee (see Figure 1). They are called cruciate because they cross each other somewhat like the letter X as viewed from both the front and the side of the joint. Both the anterior and posterior cruciate ligaments are attached to the femur and to the tibia; the names "anterior" (toward the front) and "posterior" (toward the rear) were derived from the positions of their attachment to the tibia.

The researcher in this problem is trying to determine the functions of these ligaments in the knee, and to do this is measuring strain of each as a function of extension and rotation of the knee. The knees for this research come either from amputations or recent deaths at the hospital. The present technique in this research is to coat the anterior and posterior cruciate ligaments with a radiopaque paint and then take X-ray photographs of the knee held stationary in various positions by a mechanical clamp. This method, in addition to requiring the assistance of already busy X-ray personnel, provides results which are too coarse for the purposes of the research.

If an alternate procedure to the above can be found, perhaps utilizing some variant of conventional strain gauge methods, the researcher will be able to determine quite rapidly the role of the cruciate ligaments in the knee. This knowledge should have direct impact upon treatment of various knee injuries resulting from impact as in automobile accidents, athletics, and so forth. Duke University Medical Center is not a particularly large center for treatment of this type of trauma, yet at Duke alone there is an average of around three knee injuries treated per day. Also a good method of strain measurement in this particular problem should be readily transferable to other problems in orthopedics.

Requirements and Specifications

The length of the cruciate ligament is around 3-4 cm, and the total change in length as the knee moves is 3-4 mm, a fractional change of about 10 percent. The individual ligament cross section is circular, about 1 cm in diameter, and composed of about 20-25 individual fiber bundles. The fiber bundles, each ½-1 mm in diameter, are principally composed of collagen; Young's modulus is not linear in collagen, but a neighborhood figure is 10^9 dynes/cm^2 for 100 percent elongation. The anterior and posterior cruciate ligaments are in contact at their centers for approximately half their length, so one has access to one centimeter or less length at either end of a cruciate ligament where it is not in contact with the other. The researcher wants to measure strain in individual fiber bundles of the cruciates. Whatever device is used in this high-strain problem will have to function in a conducting environment, the saline solution of the body.

A quick and reliable method of attachment to the cruciate ligament fiber bundle is needed. The knees in this research will have been freshly amputated and the tissue will be dying over a period of several hours. The behavior of the cruciate ligaments will depart progressively from that in the living body during this several-hour period. It would be undesirable to have to use much of this available time waiting for adhesives to set.

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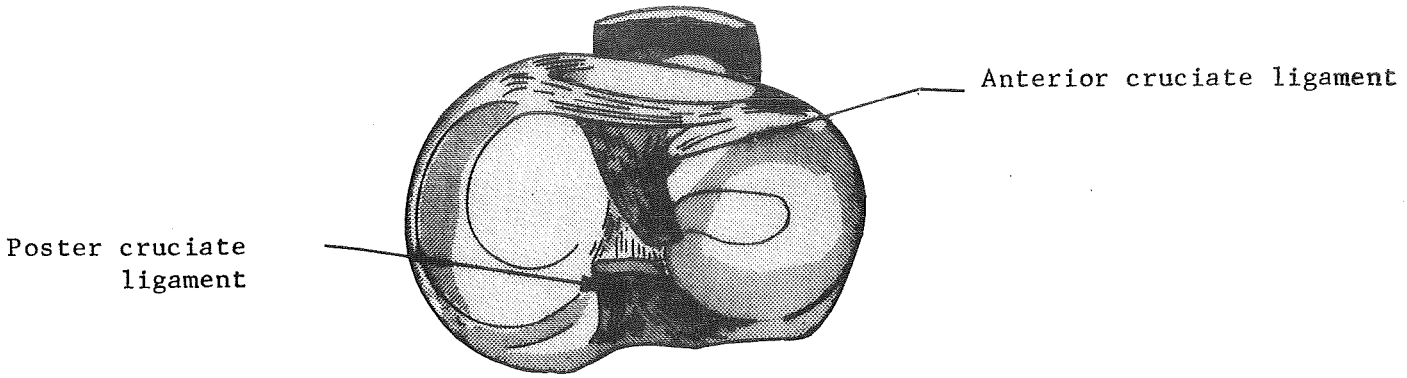

Fig. 1a.

Right Tibia viewed from above, following horizontal cut through knee joint.

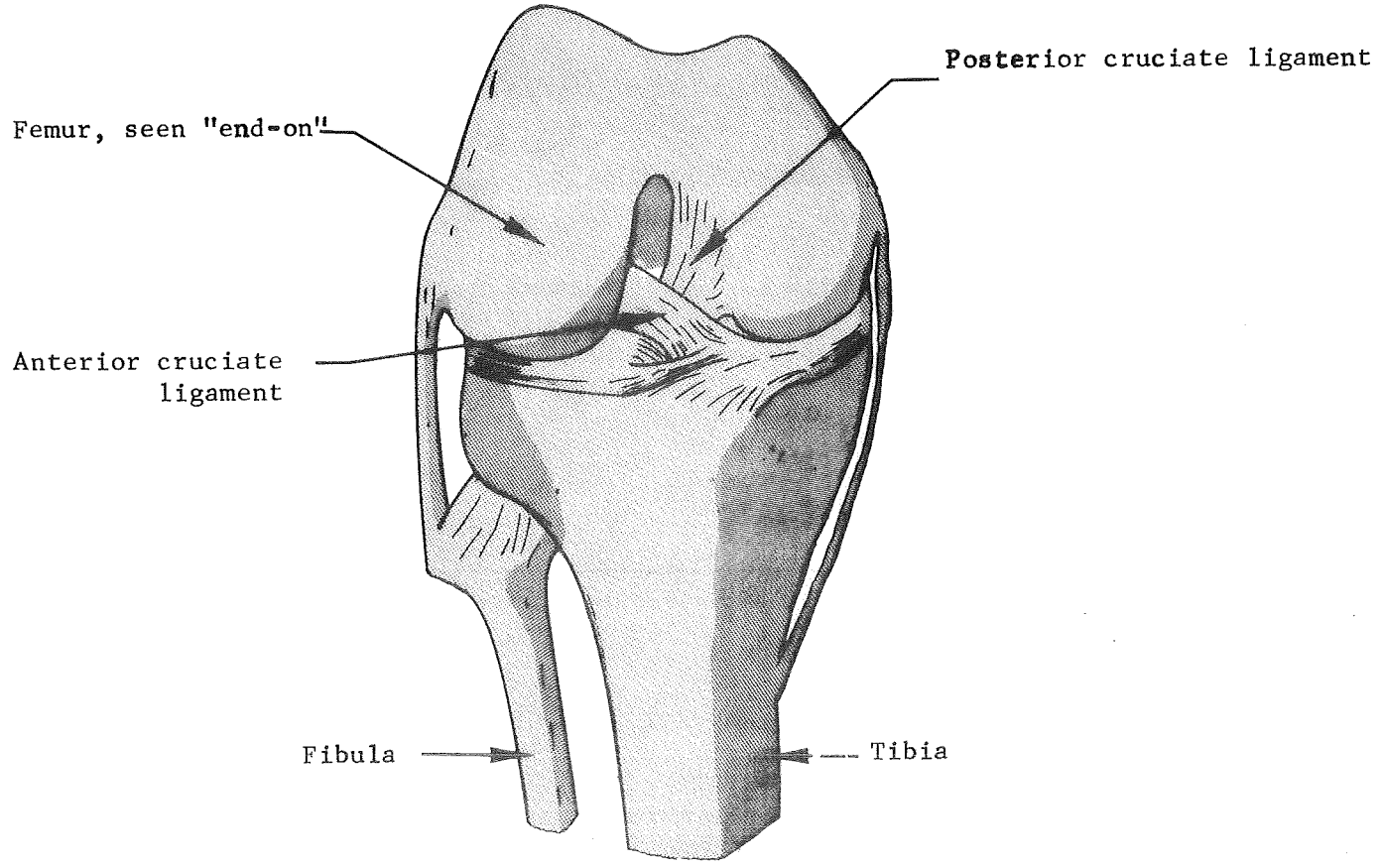

Fig. 1b.
Right knee, flexed 90^{o} and viewed from the front. Several outer ligaments have been removed for this view.

P R O B L E M S T A T E M E N T

"Tissue Oxygen Monitoring During Childbirth"

What is Needed

A method for measuring oxygen partial pressure in the scalp of an infant during childbirth is needed.

Background

Infant mortality is a matter of major concern in health care because of the high rate in this country compared with other countries and because little progress has been made since the early 1950's. Ten children out of every 1,000 births die within one day of birth and two of these ten die within the first hour.

A critical aspect of the solution to this problem is adequate monitoring of the child's condition while the mother is in labor. The most common monitoring technique in use today is the measurement of fetal electrocardiogram (ECG). Unfortunately, the heart is one of the last organs in the body to indicate changes in the body status and serious problems can develop in the child without indications in the ECG. A more valuable measure of fetal status would be to measure the partial pressure of oxygen in the tissue of the infant scalp. This would be a significant improvement in fetal monitoring and the attack on infant mortality.

Requirements and Specifications

If an electrode is required in the oxygen partial pressure measurement, the electrode must be capable of being fitted onto the infant scalp during labor without causing major tissue damage. The oxygen partial pressure varies between 15 and 30 mm Hg and a measurement sensitivity of 1 mm Hg is required.

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P R O B L E M S T A T E M E N T

"Grooves in Glass for Cell Growing"

What is Needed

A proposed method of growing oriented cardiac muscle cells requires troughs or grooves, 10 microns wide and deep with a length of several centimeters, in a glass surface. A simple method for producing the grooves is needed.

Background

The skeletal muscle (also called voluntary muscle or striated muscle) responsible for body position changes is controlled by motor neurons (nerve cells) and there is ordinarily no contraction in absence of an external nerve impulse from the neuron. An individual skeletal muscle fiber responds to neuron stimulus in an all-or-none fashion; but the muscle is made up of a large number of individual fibers of different thresholds, so the muscle has, by variation in the number of fibers contracting, a graded response depending on level of stimulus.

The cardiac muscle (heart muscle) is quite different. It has a spontaneous contraction rate when isolated from external nerves, although its rate can be modified somewhat by nerves as well as by chemical mechanisms. A single cardiac muscle cell in the heart is roughly cylindrical, 5-10 microns in diameter and 100 microns long. The entire cardiac muscle responds to a stimulus in an all-or-none fashion, conducting the impulse from point of origin in the same manner as would a single nerve cell of a single skeletal muscle cell. Until 1955 it was thought that the sarcoplasm (in effect the cardiac muscle cell liquid contents) was continuous from one cell to the next. Electron microscopy has shown this to be wrong and that a cellular membrane bounds each cell which makes more difficult the understanding of the response of cardiac muscle as a whole.

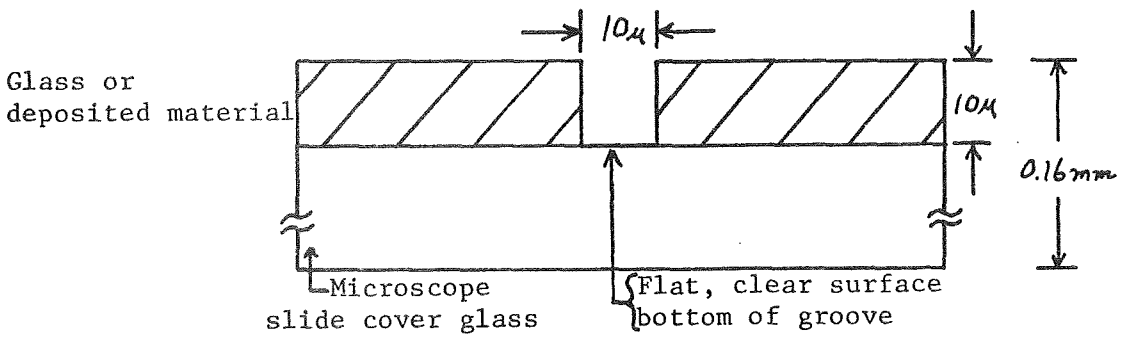
There are two ways to obtain cardiac muscle cells for experimentation: either one can grow the cells by cell culturing techniques, or one can obtain the cells from bulk section of cardiac muscle. By carefully "teasing apart" cardiac muscle, the smallest cardiac bundles that can be obtained have 6-10 interconnected cells. This makes it very difficult or impossible to perform electrophysiological measurements on single cells and on cell-to-cell processes and such measurements are necessary to understand cardiac muscle on the fundamental cellular basis. A means of obtaining a line of cardiac cells connected end-to-end and two or three millimeters long would be an accomplishment of great importance.

Some experimental evidence exists showing that cellular orientation and direction of growth can be affected by details of the substrate on which they are cultured. How and why this occurs and what variables will affect this are not completely clear, but the researchers feel there is a good chance of getting

cardiac muscle cells to grow in rectangular cross section grooves in a glass surface. When grown in a culture, cardiac muscle cells can be characterized as roughly rectangular, 2 microns thick, 10-20 microns wide, and about 100 microns long. A simple and relatively inexpensive means is needed to produce 10-micron wide, 10-micron deep grooves several centimeters long in a glass surface.

Requirements and Specifications

The grooves are to be produced on a special type of microscope slide cover glass. The cover glass is a disc 45 mm in diameter and 0.16 mm thick. The sketch below indicates the cross sectional view of the groove:



The bottom of the groove should be optically clear if at all possible because the researchers employ an inverted microscope looking upward through the glass at the cells growing in the groove. Also there is the possibility of a two-layer structure as indicated. Instead of removing glass in forming the groove, possibly some material could be added. The question of what material to add is difficult because of the cellular responses to different materials. This is why a single material (glass) with grooves might be better. There is at least some evidence, however, indicating that a layer of cellulose acetate with grooves cut through to glass might work.

A number of parallel grooves would be desirable for the initial work establishing the conditions for growing the desired linear chains of cardiac cells. The spacing between parallel grooves would not be critical, possibly 100 microns or so would do. Once the growth rules are established, the researchers eventually will want branching or "Y-shaped" grooves. The method of producing grooves should work for this shape too, if possible, Simplicity, reliability and relatively low cost (tens of dollars per glass disc instead of hundreds) are important constraints, and the researchers would prefer something which could be implemented at their university rather than require outside facilities.

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P R O B L E M S T A T E M E N T

"Respiratory Measurements During Exercise"

What is Needed

For one of the test stations in a multiphasic health-screening clinic, a means is needed for measuring respiratory gas volume and flow rate during exercise. The requirements are given in the "Requirements and Specifications" section of this problem statement; the "Background" section below discusses only multiphasic screening in general.

Background

In this country, chronic disease has surpassed accidents and infectious diseases as the major causes of death and disability. Cancer, heart disease, and stroke currently account for 70 percent of all deaths. Periodic checkups have long been recommended as a means of improving individual health, but if the decision were to be made to provide health examination for large numbers of people, practicing physicians would be overloaded; there simply aren't enough physicians now nor will there be for at least the next decade.

What is needed is a way of screening out the relatively large number of healthy or normal patients prior to physician consultation;one efficient and economical means of doing so is by use of automated multitest laboratories. M. F. Collen has popularized the term "Multiphasic Clinic" for multitest or multisensor health examinations, and multiphasic screening has come to mean the systematic gathering and handling of patient data at or before the point of physician consultation. Strongly implied in the above is the use of computers to handle the patient data, with all tests for which appropriate instrumentation exists on-line ultimately.

A fundamental assumption in the entire multiphasic screening clinic rationale is that early detection of "predisease" stations will be of benefit in subsequent therapy. This has yet to be scientifically proved. To develop multiphasic techniques and to provide a body of data to support future decisions on the role of multiphasic screening in health care delivery, a number of multiphasic clinics are now being operated on a pragmatic basis. Notable among these are four Public Health Service pilot projects at Tulane University School of Medicine, Milwaukee City Health Department, Rhode Island State Health Department, and the Brookdale Hospital Center in Brooklyn.

A number of disease or predisease symptoms may appear under physiological stress (exercise) which would not be present in a normal or resting state. Because of the assumption of benefit from early detection, the researchers at Brookdale Hospital Center Multiphasic Health Screening Clinic are planning addition of a stress test station to the clinic. At the stress test station, physiological measurements are to be carried out in the cardiovascular and pulmonary systems during exercise, and the hope is to provide early detection of respiratory disorders, latent cardiac failures, and stroke proneness.

Stress testing has not thus far been adopted in mass screening because of lack of suitable equipment and techniques; available techniques involve discomfort to the patient, give poor signals due to various motion artifacts, and are too time consuming. Certainly NASA has considerable expertise in stress testing and this should permit significant contributions to the design and operation of the stress testing station at the Brookdale Hospital Center.

Requirements and Specifications

The record of a patient's air volume (in liters) and flow rate (in liters/sec) as a function of time can provide information about the presence of asthma, emphysema, or other obstructive lung diseases. If the patient is to be exercising on a treadmill, a set of steps, or a bicycle ergometer, the instrument must have low bulk and must allow sufficient patient freedom of motion.

The following is a list of some of the relevant requirements and specifications in this problem:

1. The response time of the instrument should be less than 0.1 second and preferably 10 milliseconds or less.
2. The peak flow rate (measured for a 10-millisecond time interval) for a normal population is 351-804 liters/minute (males) and 166-614 liters/minute (females).
3. The maximum ventilation during a one-minute period for a normal population is 47-259 liters (males) and 48-177 liters (females).
4. The vital capacity (maximum volume of air which can be taken in following the maximum expiration) for a normal population is 2.06-6.7 liters (males) and 1.2-4.6 liters (females).
5. The instrument must have accuracy of 5 percent or better.
6. Apart from requiring him to breathe through an appropriate mouthpiece or mask, the instrument must not require additional patient's cooperation.
7. Ideally the instrument would have zero impedance to the patient's breathing; the maximum back-pressure tolerable is 3 mm Hg.
8. The instrument's output should allow eventual use on-line to a digital computer.
9. No motion artifacts are allowable from the patient's motion during exercise, and the instrument must have sufficiently low bulk and freedom of motion to permit that exercise.

In addition to techniques for respiratory measurements during exercise, the researchers want to know results from other research in this field, particularly as related to defining normal and abnormal patient performance.

References

1. M. F. Collen, Hospitals 41, 119 (May 1, 1967).
2. M. F. Collen, in Presymptomatic Detection and Early Diagnosis, C.L.E.H. Sharp and H. Keen, eds., London: Pitman, 1968.
3. A good reference book on respiratory system properties, functions and measurement techniques is J. E. Cotes, Lung Function, Oxford: Blackwell Scientific Publications, 1965.

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RTI/BH-2
February 1970

P R O B L E M S T A T E M E N T

"Respiratory Gas Analysis During Exercise"

What is Needed

A method is needed for measuring, on a breath-to-breath basis, the gas content of air inhaled and exhaled by a patient during exercise.

Background

The researchers are planning to add a stress-testing station to a multiphasic health-screening clinic and one of the desired measurements during stress (exercise) is the gas analysis of the patient's breath. (Problem Statement RTI/BH-1 provides multiphasic screening background information.) Comparison of the breath analysis for air inhaled and for air exhaled will give the amount of gases actually exchanged in the lungs. The combination of the gas flow and volume measurements (subject of problem BH-1) and the respiratory gas analysis of this problem will provide early detection of both obstructional and functional disorders of the pulmonary system.

Requirements and Specifications

The measurement system needed for the breath analysis during exercise must have the following properties:

1. The physiologically important gases are oxygen, carbon dioxide, and nitrogen. Oxygen measurement alone would be a significant achievement, but it would be preferable to measure all three gases. Normally for a patient breathing dry air at sea level with 760 mm Hg atmosphere pressure, the alveolar pressures (the pressures within the lung, hence typical of breath content when exhaling) of oxygen, carbon dioxide, and nitrogen are 103 mm Hg, 40 mm Hg, and 570 mm Hg, respectively. Corresponding values for dry air (hence air inspired) are 159 mm Hg of oxygen, 2.3 mm Hg carbon dioxide, and 598 mm Hg nitrogen.

2. The normal respiration rate is 12-20 breaths per minute, but in exercise the rate could be as high as 80 per minute. The response time of the gas analysis measurement must be short enough to measure well within one respiratory cycle. For instance, ten measurements in one cycle at a 60 breath per minute respiration rate would require a response time shorter than 0.1 second. Alternatively, some type of gas sample trap-and-hold technique could be employed with a slower response gas monitor, but this is much less desirable.

3. Since the patient will be exercising on a treadmill or a bicycle ergometer, the gas measurement system must not interfere with his motion, and there must be no motion artifacts in the system output.

4. The output should be in a form allowing eventual connection on-line to a computer.

The researchers are also interested in learning of other measurements of respiratory gases during exercise; this should help in determining normal behavior for different population groups.

References

1. J. E. Cotes, Lung Function, (Oxford: Blackwell Scientific Publications, 1965) provides general reference material on all aspects of the respiratory system.

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RTI/BH-3
February 1970

P R O B L E M S T A T E M E N T

"Blood Pressure During Exercise"

What is Needed

A means is needed for recording the blood pressure of a patient while he is exercising.

Background

The researchers are planning a stress-testing station to be added to a multiphasic health-screening clinic; background information about this is given an problem statement RTI/BH-1. The overall goal is early detection of pulmonary disorder, stroke proneness, and latent cardiac disorders, and one of the important physiological parameters to be measured during exercise is the patient's blood pressure.

Requirements and Specifications

The range of pressures to be encountered will be within 0-300 mm Hg and a typical adult man may have a systolic/diastolic pressure of 130/80 mm Hg. The systolic is the peak pressure and the diastolic is the minimum or residual pressure; these are usually measured using the familiar inflatable cuff over the brachial artery in the upper arm. The pulse rate, and thus the number of blood pressure cycles, will lie within the range 0-4 beats per second. It would be desirable to measure the blood pressure continuously throughout the pressure cycle. The pressure should be accurate to within several mm Hg.

The method used to measure blood pressure should be noninvasive and nontraumatic, and should not require the patient's cooperation. The instrument used must be easy to apply reliably to the patient, and must be free of motion artifacts from the patient's exercise. The part of the instrument attached to the patient must not be unusually bulky nor must it restrict his motion during exercise. The instrument should be simple, reliable, easy to maintain, should possess self-calibration capability if appropriate, and the output must be suitable ultimately for input to an on-line computer.

The researchers are also interested in other studies of blood pressure as a function of exercise, particularly information helpful in defining normal and abnormal performance for various age groups.

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RTI/BH-4
February 1970

P R O B L E M S T A T E M E N T

"Blood Flow During Exercise"

What is Needed

A noninvasive means is needed for measuring blood flow in a patient's artery during exercise.

Background

The researchers are designing a stress-testing station to be added to a multiphasic health-screening clinic. (Problem Statement RTI/BH-1 provides background information on multiphasic screening.) Some of the physiological measurements to be performed under stress (exercise) are directed toward detection of stroke proneness. A stroke occurs so suddenly because it is due to the failure of a portion of the circulatory system carrying oxygenated blood to the brain. Hence, measurements of blood vessel characteristics and dynamics, particularly measurements detecting partial occlusion of a vessel, are potentially capable of providing early detection of stroke proneness. For mass screening applications, the measuring technique desired is blood flow rate in the carotid arteries (the pair of major arteries, one at either side of the neck, supplying blood to the head).

Requirements and Specifications

As already indicated, the method used to measure blood flow rate in the carotid arteries must be noninvasive or at most semiinvasive. That is, small electrodes inserted into the blood stream (possibly for some type of electromagnetic flowmeter) might be tolerable for research purposes, but cannulation or catheterization definitely are not tolerable. The measurement technique must not be adversely affected by the patient's motion during exercise nor must that motion be unduly hindered. Ideally, the measuring instrument would be easy to apply quickly to the patient, would be simple and reliable to use, and would possess self-calibration features. The output should be in a form suitable for eventual use on-line with a digital computer.

For noninvasive measurements of blood flow, the techniques available are quite limited. Basically, information about flow has to be carried into and out of the blood stream through the skin and the blood vessel walls; available for this would be electromagnetic radiation and pressure waves (i.e., sound). Nuclear magnetic resonance techniques permit some flow measurement, but the method is too complex and the equipment probably too bulky for the present application. Perhaps some form of Doppler-shift ultrasonic flowmeter[1] is a possibility.

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[1] R.F. Rushmer, D.W. Baker, and H.F. Stegall, Journal of Applied Physiology, 21, 544-566 and 707-711 (1966).

The researchers are also interested in detail of other experiments on blood flow in the carotid arteries and on other peripheral blood flow as a function of exercise, particularly as those experiments can contribute to defining normal and abnormal results for different population groups.

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RTI/BH-5
February 1970

P R O B L E M S T A T E M E N T

"ECG During Exercise"

What is Needed

Electrocardiogram signals free of motion artifacts must be obtained for patients who are exercising.

Background

The researchers are planning a stress-testing station for a multiphasic health-screening clinic and one of the important measurements during stress (exercise) is the patient's electrocardiogram. (Problem Statement RTI/BH-1 provides multiphasic screening background information.) The principal difficulty anticipated is in the electrode connection to the patient. A conventional ECG electrode may, because of perspiration and motion, loosen and fall off or it may stay on but give poor, electrically noisy signals. Electrodes free of these problems are needed.

Requirements and Specifications

In this multiphasic screening use, the patient's ECG electrode must permit freedom of motion during exercise on a treadmill or a bicycle ergometer, must not cause patient discomfort, and must be easy to apply reliably. Probably a technician, not a doctor, will be attaching the electrodes to the patient. For this screening application, cost per patient processed must be minimized and electrodes must not require much time for attachment or removal.

The researchers are also interested in the results of other experiments recording electrocardiograms under physical stress, particularly experiments whose data can help in defining normal and abnormal results for different population groups.

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P R O B L E M S T A T E M E N T

"Exercise Capacity and Standardization in Human Stress Testing"

What is Needed

Information and experimental data is needed on various types of exercise tests, particularly information related to standardization of exercise tests and to definitions of normal performance for different groups within the general population.

Background

The problem originators are designing a stress-testing station to be added to a multiphasic screening clinic. (Problem RTI/BH-1, February, 1970, provides multiphasic screening background information.) At the stress-testing station, a number of physiological measurements will be carried out for a patient during stress (exercise). In addition to planning the physiological measurements,attention must be given to the exercise procedure to be used.

There are two ways one could administer exercise, by maximum or by submaximum effort techniques. In maximum effort techniques the subject is either required to work at a given load level for as long as he can maintain that output or else is asked to put out his maximum effort for a given time. Submaximum effort techniques generally require the subject to maintain a given output level for a preset time. Devices on which the exercise is actually performed include the bicycle ergometer, the treadmill, and one or several steps.

A number of studies have been done on various physiological processes as a function of exercise, and the problem originators would like to utilize some of this data in defining normal vs. abnormal performance of the subjects in the stress-testing station of the multiphasic screening clinic. Unfortunately, there has been little or no standardization of the different exercise tests in the past, each experiment having used different arbitrary work levels and schedules.

In planning the stress-testing station, the researchers have to decide on an exercise test protocol to be followed. Information about any exercise-testing which NASA has done or is doing would be valuable for planning and designing the stress-testing station.

Requirements and Specifications

Two different types of experimental information are needed. First, information is needed on the standardization of different possible exercise tests of both the maximum effort and submaximum effort types. Second, information is needed defining normal and abnormal performance on these tests by different population groups. Although the stress-testing station will be

processing a heterogeneous "off the street" population, data from even one narrow group (25-year-old men in excellent physical condition, as an example) would be helpful to the researchers.

The researchers have already manually searched the open literature in this area. This problem statement seeks information about NASA-sponsored work which can help in designing the stress-testing station, planning the exercise protocol to be followed, and defining normal performance parameters for the populations to be screened.

References

1. R. J. Shephard, Int. Z. Angew, Physiol. einschl. Arbeitsphysiol., 23, 219-30 (1966), presents one comparison of different exercise tests for assessing cardio-respiratory fitness.
2. L. G. Ekelund, Ann. Rev. Physiol., 31, 85-116 (1967), is a very good review article covering all aspects of exercise.
3. T. Sjostrand, ed., Clinical Physiology. Pathophysiological Basis and Practical Application (Philadelphia: J. B. Lippincott Co., 1967) includes a chapter on exercise tests.

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RTI/TU-1
January 1970

P R O B L E M S T A T E M E N T

"Shock Wave Measurement"

What is Needed

A pressure transducer for measuring shock waves in the brain is required.

Background

Brain damage due to accidental injury from falls, automobile accidents, and other accidents is a significant cause of injury and disability in this country. For example, last year there were 140,000 disabling accidents involving brain damage in work related cases alone. The damage occurs when a blow to the skull is transmitted through the bone to the underlying brain tissue. In order to better understand the forces exerted on the brain tissue, much theoretical work has been conducted. Two different theories of considerable merit have arisen but no experimental work has been conducted which will verify exactly how the stresses occur in the brain under varying conditions of applied stress. Verification of these stress patterns is important in understanding the damage done to brain tissue from a blow to the head.

The researcher is planning to conduct experiments on an experimental model of the head by applying a sharp blow to the model and measuring the forces at various point in the model. The second phase of the program will involve repeating these measurements by implanting the pressure transducer in the skull of primates.

Requirements and Specifications

A shock wave pressure transducer is required which can measure a negative pressure of 3 mm Hg with a response time less than 100 microseconds. The transducer diameter must be between 1 and 4 millimeters.

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RTI/TU-2
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P R O B L E M S T A T E M E N T

"Respiratory Rate Measurement"

What is Needed

A simple, unencumbering method of measuring respiratory rates in children is needed.

Background

Respiratory diseases are the major cause of illness in children from infancy through adolescence. Some of the more serious types of respiratory diseases include asthma, cystic fibrosis, and bronchitis. Much research is presently being conducted both in the causes and cures of respiratory diseases as well as better methods of diagnosis of the diseases. This problem statement is devoted to a method of improved diagnosis which will, in turn, improve the treatment of respiratory diseases.

One valuable index for lung disease is the quiet activity respiratory rate which must be monitored for children in a normally quiet play period. If this rate is studied for the same patient over a period of months, much information can be gained about the condition and changes in condition of the patient's lung. The reason that rate is important is because it is related to lung compliance or stiffness. For example, if disease stiffens the lungs, the body will adjust to the disease by breathing more shallowly and more rapidly. In the case of asthma, which restricts the air flow, the patient will breathe more deeply and slower. Thus, respiratory rate is an important parameter in diagnosis of lung disease.

Requirements and Specifications

The patients will range in age from infancy to adolescence, and the monitoring will occur in a hospital clinic. The rate measurement method should not encumber the child, and must allow quiet play to occur. It is anticipated that the data will be transmitted to signal processing equipment by a small unit on the child, but the telemetry aspect of the problem will be considered in a subsequent problem statement.

The range of rates will be from 12 to 80 breaths per minute and a precision and accuracy of 0.1 breaths per minute is required.

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RTI/TU-3
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P R O B L E M S T A T E M E N T

"Lung Sound Detection"

What is Needed

A method is required for detecting breathing sounds on the chest surface and displaying these sounds graphically.

Background

The major cause of illness in children from infancy through adolescence is respiratory diseases of which the more serious forms include asthma, cystic fibrosis, and bronchitis. Significant research is being conducted both in the causes and cures of respiratory diseases as well as better methods of diagnosis of the diseases. This problem is devoted toward a method of improved diagnosis which will, in turn, improve the treatment of respiratory diseases.

The respiratory system consists of the lungs and the system of tubes or ducts which feed air into the lungs. Air proceeds from the nose and mouth through the trachea which is the central air duct. From this central tube, two branches diverge that eventually feed air into the two lungs. These two branches, called the right and left bronchus, eventually subdivide still further into smaller tubes called bronchial tubes. Each bronchial tube feeds air into and out of a section of the lung, and each tube has a symmetrical counterpart in the other lung.

One useful and simple method to determine if a portion of the lung is performing properly is to listen to the sounds made by air flow. Usually, this is done with a stethoscope, but only one section of the lung can be heard at a time. To compare sections of the lung, it would be useful to compare the sounds generated by a section of the lung with the sounds generated by the symmetrical counterpart in the other lung.

The basic problem is to detect the sounds from two sections of the chest wall by microphones and display the sounds graphically either on a strip chart or on an oscilloscope. Comparison will be made on the amplitude, frequency, and time interval between appearance of the two sounds.

Requirements and Specifications

The frequencies of interest will be 50-15,000 hertz. Breathing rates normally will be 25 breaths/minute although a range of 12 to 80 may occur. The amplitude of the sounds of interest is not known. Measurements will be made on children from infancy to adolescence in a hospital clinic.

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P R O B L E M S T A T E M E N T

"Measurement of Change in Heart Wall Dimensions"

What is Needed

A method is required for measuring the change in dilation of a small section of heart wall during a complete pumping cycle.

Background

Heart disease is the focus of a major research effort in this country and recent dramatic advances have been made in this effort using the artificial heart. One function of the artificial heart is to provide partial assistance to a failing heart, but during the period of assistance some measure of the output of the human heart is required. This measurement is necessary in order to determine the output of work required from the artificial heart.

The usual method of determining the output of the human heart is to measure the volume of the left ventricle, the chamber of the heart that pumps blood to the body after the blood has returned from the lungs. The left ventricular volume can be measured by two techniques called dye indicator, and biplaner angiography, but neither method produces an instantaneous output. An instantaneous measurement is necessary so that rapid changes can be made in the artificial heart ouput.

Recently a new technique for measuring left ventricular volume has been developed which does allow the desired instantaneous measurement. This method involves measuring the stretch or dilation of a small section of the heart wall and this stretch or dilation can be correlated with left ventricular volume which, in turn, can determine the work required for a cardiac assist device.

The measurement of stretch or dilation of a section of the heart wall is relatively simple when the chest has been opened by surgery. Then, a mercury strain gauge can be attached to the heart wall to measure the changes in dimension. However, this strain gauge method has the severe limitation that the chest wall must be opened. A more desirable technique would be to measure the changes in dimension of a small section of the heart wall without opening the chest wall. It would be possible to insert a catheter into the heart and attach some measurement device to the tip of the catheter.

Two approaches to this problem are possible. The first approach is to have a direct attachment to the heart wall at the end of the catheter. For example, a pair of hooks could project from the catheter into the heart wall

and the change in distance between these hooks could be measured by a strain gauge. The second approach would be an indirect method of dimension measurement by ultrasonic techniques. For example, an ultrasonic doppler tip catheter placed against the heart wall may provide the desired infromation.

Requirements and Specifications

The distance covered by the measurement must be less than 20 millimeters. A 25-50 percent change in dimension is expected and the accuracy of measurement must be better than 5 percent. The accuracy of interest is the relative change and not the absolute change in dimension.

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P R O B L E M S T A T E M E N T

"Measurement of pCO_2, pO_2, pH in Blood"

What is Needed

An on-line, real time transducer for monitoring blood gases (O_2, CO_2, pH) in patients during the critical phase following surgery is needed.

Background

Surgery is a common event in modern medicine but it still causes significant danger to the patient. To reduce this danger, most hospitals carefully monitor a patient's condition in the most critical period immediately following surgery. Three of the many measurements of value during this period are pCO_2 (partial pressure of carbon dioxide), pO_2 (partial pressure of oxygen), and pH (acid/base relationship) of the blood.

Analyses of blood gases and pH provide insight into the way that the body is utilizing the available oxygen and discharging the waste carbon dioxide. This utilization includes not only lung function but also tissue function. These measurements can tell the physician many things including onset of shock. In addition, the measurements can assist in assessing the patient's general progress.

Existing methods for blood analysis consist primarily of sampling techniques in which blood samples are withdrawn sequentially and tested. An on-line, real time method would provide not only more information but would reduce the effort required of the nursing staff and would free them for other activities.

Requirements and Specifications

The transducer should allow continuous monitoring of the blood gases (O_2 and CO_2) and blood pH. If a probe is inserted into the blood vessel, the diameter should be less than 2 millimeters in diameter, and preferably less than one millimeter. The range of values is given in the following table.

Value	Normal		Extreme Range
	Arterial	Venous	
pO_2 (mm Hg)	93	40	10-760
pCO_2 (mm Hg)	40	46	15-120
pH	7.40	7.37	6.70-7.70

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P R O B L E M S T A T E M E N T

"Technique to Determine Capillary Fragility"

What is Needed

When sufficient mechanical stresses are applied to capillaries, the walls rupture and the red blood cells are released into the surrounding tissues. A reproducible measurement technique is needed for determining the threshold stress for this process and thereby providing a quantifiable measure of the capillary fragility.

Background

The capillaries are the smallest blood vessels in the body, with diameters in the range 10-20 microns. Their walls are normally impermeable to the red blood cells (diameter about 8 microns) but under mechanical stress the walls can rupture and release the red blood cells into the surrounding tissue; the resulting minute rounded spot of hemorrhange on the skin's surface is called a petechia. Petechiae may be seen by the unaided eye or with the aid of a low power magnifier. The colorful effects in bruises derive their color from the breakdown of red blood cells during the body's natural cleanup and restoration process following the capillary rupture which occurred during the blow which caused the bruise. The fragility of capillaries varies with certain diet factors and with temperature, and the fragility is markedly increased in certain diseases such as scurvy, leukemia, and hemorrhagic fever. There is also some evidence of a correlation between capillary fragility and diabetes.

A reliable and standardizable method of capillary fragility measurement would be very useful in experimental studies of hemorrhagic disorders as well as for a clinical approach to the question of whether a vascular abnormality is present. Although considerable work has been done on this, there has been little practical application to date because of the lack of standardization of the tests and the lack of agreement about their outcome.[1]

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[1] A general review of the subject is "The Determination of Evaluation of Capillary Resistance--A Review of Methodology," J. Dramar, Blood 20, 83-93 (1962).

Available methods fall into two general categories: the positive pressure method in which the veinous blood return of the arm is dammed with a cuff or elastic band in order to increase the intracapillary pressure; and the negative pressure method in which a suction is applied to the skin to create negative pressure which is transmitted to the capillaries. Either a standard pressure profile vs. time is used and the number of petechiae appearing by a given time are counted, or the pressure required for first appearance of petechiae is noted, or some combination of these is employed.

The researcher in the present problem is interested in possible correlation between ease of production of bruises in poultry and the presence of certain mold toxins in the poultry diet. A reliable capillary fragility measurement technique will aid this investigation and will also have important application in human medicine as indicated above. At present, the bruising is produced by a spring-loaded hammer arrangement in which the force of the blow is variable; there is no simple way to assign a number scale to this method, and the observation becomes either "bruise" or "no bruise" for any setting of the apparatus.

Requirements and Specifications

For human medicine, a capillary fragility measurement technique should be reproducible, simple to perform, and should involve a minimum of discomfort to the patient. In the immediate case of poultry, the comfort requirement can be relaxed but the physical requirements are different (an arm cuff is clearly inappropriate). The chicken wing web, a thin skin at the leading edge of the wing, may be transilluminated if desired, but it will not be practical to try to hold a live chicken for microscope observation of a wing.

The basic technique will probably consist of application of some force increasing with time and noting the time at which the capillary walls first rupture; detection of this event is the main problem.

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P R O B L E M S T A T E M E N T

"Analysis Techniques for Physiological Data"

What is Needed

The researchers are examining the basic mathematical theory for the analysis of electroencephalograms or of related physiological data. They need to know of recent developments in the theory of nearly periodic, nearly stationary stochastic processes.

Background

An electroencephalogram (EEG) is simply a time-recording at the head's surface, of electrical signals generated by the brain. At present, this record can be correlated with certain overall physical states such as sleep, but it is possible that refinement of the mathematical analysis of the EEG would lead to its use in the future for diagnosis of specific and local brain disorders such as small rumors.

There exists a certain amount of electrical noise in the recording process, and the EEG itself would be characterizable as basically stochastic. However, two characteristic rhythms have been identified, the alpha and the beta. The alpha activity has a frequency of 8-13 Hz, relatively high amplitude, and is primarily associated with the resting condition. The beta rhythm, frequency 18-30 Hz, has lower amplitude and corresponds to an alert state. Neither the alpha nor the beta rhythms are completely periodic nor are these stationary processes, but the assumptions of stationarity and periodicity have been made in virtually all EEG analyses to date.

These assumptions and their consequences are the main concern of the researchers in the present problem. It may be possible that a different mathematical model and different fundamental assumptions are more appropriate for EEG analysis and that under a different model the amount of useful information derived from EEG analysis could be considerably increased.

Requirements and Specifications

The researchers need to know of any developments in the general theory of stochastic processes and particularly those developments related to non-periodic, nonstationary processes. They are not interested in specific computer programs now available to carry out analysis by auto- or cross-correlation techniques or Fourier transform techniques; it is the basic theory itself which holds their interest.

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P R O B L E M S T A T E M E N T

"Undersea Telemetry"

What is Needed

A means is needed for telemetry of physiological data from a free-swimming seal in the ocean.

Background

The researcher is conducting a research program in the fundamental mechanisms of gas transport in mammalian blood and tissues. An important practical application of this information is in the area of gas mixtures and scientifically determined decompression tables for deep diving by humans. Deep-diving mammals such as porpoises, seals, and whales have a physiology remarkably suited for diving, and the understanding of the gas processes during the dive of these animals will contribute greatly to the solution of human diving problems.

Some experiments performed with animals suggest that physiological measurements carried our on tethered animals yield results significantly different from similar measurements telemetered from free animals. If raised in presence of humans only, a seal will swim and dive in the ocean normally but will disregard the presence of other seals and return to the humans when finished swimming. Such an animal offers the prospect of obtaining valuable physiological data on the diving process, and the present problem is to find or develop appropriate undersea telemetry equipment.

Requirements and Specifications

A seal weighs around 90 pounds and has a highly efficient shape for motion in the water; an appropriate telemetry signal conditioning and transmitter package should be light in weight and have physical dimensions as small as possible in order to minimize the disturbance of the seal's natural swimming. At least four channels should be available for data transmission. The minimum range should be several hundred feet but transmission distances of up to a mile would be more desirable. The unit must be capable of operating under sea water at depths of several hundred feet. Information to be transmitted includes heart rate, temperature, depth beneath the water, and oxygen tensions in blood or tissue monitored at several points if possible. Heart rate will be 0-10 Hz. The other signals will exist as varying voltage levels to be transmitted at 1% accuracy or better. Each of the functions to be telemetered presumably will have its own plug-in pre-amplifier which can be designed to deliver a standard signal range to the main-frame modulator and transmitter unit.

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P R O B L E M S T A T E M E N T

"Measurement of Tissue Gases In Vivo"

What is Needed

A measurement technique is needed for measurement of gas tensions in live experimental animals.

Background

The researcher is conducting a research program in the fundamental mechanisms of gas transport in mammalian blood and tissues. The following is a list of some of the different research areas within this program:

(1) Oxygen metabolism and kinetics in tissue--experimental measurements by polarographic techniques of oxygen respiration rates in tissue slices of varying thicknesses, investigations of theoretical models for oxygen transport by enzyme kinetics, passive diffusion, or carrier mechanisms.

(2) Oxygen transfer in blood and detailed enzyme chemistry of this process--determination of the mechanisms controlling various enzyme levels in cells, effects of air pollutants on the enzyme processes in rat's blood.

(3) Inert gas transport in tissue--investigation of passive diffusion processes by tracer chemistry techniques using a radioactive krypton isotope.

(4) Research on deep diving by humans--effects of different gas mixtures on human metabolism, details of decompression processes upon resurfacing.

The above list is not complete and is given as an illustration of the importance and impact of the research program.

The researcher would like to measure gas tensions (partial pressures) in tissue in living experimental animals. If at all possible, he wishes to determine gas concentration gradients in the tissue between blood capillaries. Such an ability would be extremely important and would open up a wide new class of experiments in this field.

Requirements and Specifications

The important gases are oxygen and carbon dioxide with some interest also in nitrogen, helium, and argon. A method of measuring all of these is very desirable but the researcher would be interested in any single gas measurement technique. A possible candidate might be a mass spectrometer.

The major difficulty will probably come from the desire to measure inter-capillary gas tension gradients. The capillary diameter is 8 microns

and the average distance between capillaries is 50-100 microns; a gradient-measuring technique could not have a sensing area with much larger than 10-micron dimensions. A reasonable estimate of average tissue oxygen tension is 25-42 mm Hg, although values in subcutaneous tissue have been observed in the range 8-62 mm Hg. Carbon dioxide tension is in the range of 31-58 mm Hg. While it is eventually hoped possible to build a miniature tissue gas tension measuring system for telemetry with free-roaming experimental animals, a first system for such measurements can be virtually any size apart from the inter-capillary gas sampling device itself.

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P R O B L E M S T A T E M E N T

"Data Compression Techniques: Software"

What is Needed

The researcher wants to know about computational techniques developed for data compression or data redundancy reduction.

Background

There are not enough doctors now. Even if a decision were made tomorrow to sharply increase the output of the medical education system, about a decade would elapse before the increase would appear in the number of doctors in clinical practice. A partial solution to the problem of health care delivery is a more efficient utilization of the doctor's time and talents, and here is where computer and electronics technology should make a large contribution. For instance, an appropriate hospital-to-hospital data transmission system (using digital computers at each hospital) would permit medical specialists at a large medical research center to assist the more general staffs at smaller outlying hospitals. The information to be transmitted would include electrocardiograph signals and X-ray images.

Taking the X-ray as an example, there is clearly a large degree of redundancy in the image. Large connected areas of the image are one density, and the real medical information content occurs at the regions where the density is varying (thus defining edges of bones or organs). Instead of digitizing the image and transmitting directly, computer processing of the digitized image may permit substantial reduction in the redundancy of information to be transmitted. A redundancy reduction, or data compression, by a factor of ten or more may be possible. This will permit reduction in bandwidth necessary in the transmitter link, hence reduction in cost, and may make the difference between this approach being feasible or not for health care delivery. Also there may be reasons to wish storage of X-ray images in computer memories. Here again, an order of magnitude data compression, leading to corresponding reduction in computer memory required, can make the difference between being possible and not being possible.

The researcher is one of a group at the Duke University Community Health Science Department which is planning alternative future health care systems built around data transmission, processing, and storage techniques. He wants information about computer programming techniques in data compression for this system planning. Although the numbers of bits involved are very different, he is interested in both ECG signals and X-ray images.

Requirements and Specifications

The ultimate use will be sufficiently specialized in terms of the computer and its hardware interfaces that the researcher and his colleagues will have to write completely new programs for this task. They are well capable of doing

so. However, considerable saving of time will occur if they can be provided with good program documentation from computer programs performing data compression. Such documentation should include general discussion and appropriate flow charts as well as the actual program source listing itself.

References

1. L. W. Gardenhire, "Data Redundancy Reduction for Biomedical Telemetry," in Biomedical Telemetry, C. H. Caceres, ed., New York: Academic Press, 1965.

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P R O B L E M S T A T E M E N T

"Mathematical or Computer Methods for the Determination Of Material Properties of Cardiac Muscle"

What is Needed

(1) Theoretical elasticity and computer software developments which utilize geometrical and external force data to determine stress and strain distributions in elastic and viscous materials are needed.

(2) Materials science software which utilizes time and spatial stress and strain distributions to characterize viscous and nonviscous material properties is needed.

Background

A problem of major concern to the clinical cardiologist is to evaluate the time-varying properties of cardiac muscle. A knowledge of these properties would be very beneficial to the clinician in characterizing muscular diseases by noting abnormalities in the values of properties. Such an indirect determination of cardiac diseases would also be valuable to surgeons in deciding whether or not to undertake cardiac surgery.

Clinical cardiologists in major medical centers obtain simultaneously ventricular pressures from cardiac catheterizations and chamber dimensions from cineangiocardiograms. This data is a major consideration in performing cardiac diagnosis. However, a more exact diagnosis could be performed if this data could be utilized to determine the material properties of the cardiac muscle. This requires the development of adequate analytical or numerical models in myocardial mechanics.

Requirements and Specifications

The only in vivo experimental data that can be obtained for determining these properties are closed-chest determinations of the ventricular dimensions by cineangiography and the ventricular pressure by catheterization. The in vivo data are corrupted by noise and are probably accurate to approximately two significant figures. Thus, proposed methods should be stable and accurate when there is considerable noise in the data.

References

The following three references provide a good starting point for further reading in this problem from the cardiologist's viewpoint.

1. "Myocardial Methanics: Tension-Velocity-Length Relationships of Heart Muscle," D. L. Fry, D. M. Griggs, and J. C. Greenfield, Circulation Research, Vol. XIV, 73-85, 1964.

2. "Left Ventricular Stresses in the Intact Human Heart," I. Mirsky, Biophysical Journal, Vol. 9, 189-208, 1969.

3. "Myocardial Force-Velocity Relationship in Clinical Heart Disease," P. G. Hugenholtz, R. C. Ellison, C. W. Urschel, I. Mirsky, and E. H. Sonnenblick, Circulation, Vol. XLI, 191-202, 1970.

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P R O B L E M S T A T E M E N T

"Automated Measurement from Coronary Angiograms"

What is Needed

A method of digital image processing is needed for performing a large number of position measurements for specified points in a sequential series of coronary angiograms.

Background

A technique has been developed to determine myocardial contractility or functional character of the cardiac muscle. This technique should be particularly useful in determining the location and extent of loss of muscle function, and as a means of determining effectiveness of surgical procedures designed to improve cardiac function by improving the blood supply to the heart. The technique is thus suitable both pre- and post-operatively to determine coronary revascularization following treatment. The most appropriate surgical procedure or treatment to improve cardiac blood flow, and in turn cardiac function, can be determined by this technique which is based upon measurements taken from sequential coronary angiograms.

A coronary angiogram is an X-ray image of the heart taken after injection of a radiopaque dye into the coronary artery; this procedure makes the coronary artery and the arterial bifurcations visible. The analysis technique above relies on measurements of dimensional changes of various portions of cardiac muscle during a cardiac cycle. These linear dimensional changes can be related directly to cardiac muscle function. The measurement of these arterial bifurcations recorded in coronary angiograms. Two separate angiograms are needed, a front-back view and a side view, to determine the location in three-dimensional space of a specified bifurcation. The distance between two bifurcations is a measure of the dimension of the intervening muscle at that instant of time.

At present this procedure is implemented manually. About 20 specific bifurcation points are recorded on the two X-ray views, and the positions of these points are then recorded over several complete cardiac cycles by angiograms exposed every 1/60 second. At 60 frames per second, two projections, 20 specified bifurcations and a total of several seconds of cineangiograms, the required determination of position changes and their time course is an exceedingly difficult and lengthy task. A reasonable method of automating this analysis of the angiograms is clearly needed if this technique of cardiac function analysis is to achieve clinical importance.

Requirements and Specifications

The automated reading of the 35 mm X-ray film strips should provide rapid and accurate information on the position of specified arterial bifurcations. Accuracy should be compatible with image resolution on the order of 500 x 500 image resolution elements. It would be acceptable and probably desirable to manually identify (possibly by a light pen or similar technique) on the first film frame the specific bifurcation points to be used, and have the film reading system automatically follow the location of these points in the subsequent frames.

This problem's originators already have a Sigma 5 computer and a considerable amount of experience in interfacing and programing the computer, both in FORTRAN and SYMBOL. They also have some of the hardware components needed for image digitization. The NASA information sought is primarily in the computer programming area although hardware details are also of interest to the researchers.

One approach would be to digitize each entire film frame and apply pattern recognition techniques. This is difficult and probably very inefficient for this problem however, because at each frame the positions of the twenty or so desired points are already fairly well known from the analysis of the preceding frame. What is needed is a method of identifying and locating these points whose neighborhood values are already known.

Possibly some of NASA's work in benchmark recognition or in fiducial or reference mark location for subsequent image distortion corrections may be applicable to this problem. One possibility might be some type of local or neighborhood correlation analysis technique to determine the position shift of bifurcation point between the film frame being analyzed and the immediately previous already-analyzed frame.

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P R O B L E M S T A T E M E N T

"Real Time Data Acquisition During Batch Processing"

What is Needed

Information is needed concerning computer programming to permit asynchronous real-time data acquisition during batch processing using an IBM 1130 Model 2B computer.

Background

The IBM 1130 computer is used by a research group studying the process of aging. A number of different measurements including electrocardiograms (ECG) and electroencephalograms (EEG) are being carried out at one-year intervals on a selected group of several hundred older people. When this longitudinal study is completed five or more years from now, valuable data on aging processes and changes will be the result. The computer was obtained for analyzing the EEG and ECG's in this project but is also heavily used for a number of statistical analyses and other computations, all performed in batch processing. The usefulness of the computer would be considerably increased if it could be used for asynchronous real-time data collection during batch processing upon a suitable interrupt from the external data source.

Requirements and Specifications

The computer is an IBM 1130 Model 2B (8 K words, 3.6 microsecond cycle time, built-in disk) with an IBM 1132 printer, an IBM 1442 reader-punch, and a Redcor A-D converter and 1130 interface, operating with the IBM Disk Monitor System Version 2. The programming task, to be done in 1130 Assembler language, will have the following time sequence:

a. The 1130 is operating normally on a batch-processing job.

b. An asynchronous interrupt signals that data collection is to occur.

c. The current batch job is rolled out onto the disk and the data collection and conversion routine is rolled in from the disk. Timing is not critical in this problem and several seconds may be taken in this step.

d. The data is collected and stored on the disk for later batch processing. The data collection process lasts only several seconds in this application.

e. At the end of data collection, the initial batch job is restored and the system continues operating as in step a., (until the next interrupt occurs, when the whole cycle will be repeated).

Information is desired which is related to the experience of other 1130 users in doing similar data collection upon interrupts; the information can range from program listings and documentation through discussions with 1130 users to identify possible problems or difficulties which might be encountered. If this information can be found, the researchers in this problem will be able to do the necessary programming in a time considerably shorter than would be the case without this help.

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P R O B L E M S T A T E M E N T

"A Respiration Alarm"

What is Needed

A simple alarm is needed to warn nurses in the event of respirator failure.

Background

The Goldwater Memorial Hospital of the New York University Medical Center operates one of the largest respirator centers in the United States. Users of these respirators are permanently disabled, e.g., stroke victims, paralysis victims, and others permanently unable to respire themselves as a result of accident or disease. This means that the respirators must be used on the patients continuously and for long periods of time. The respirators have battery-operated alarms connected to their mechanisms which function when the respirator becomes disabled. The alarms are not foolproof, however, because the alarm system itself is subject to failure. Circuit failures can, and do, occur. In addition, the batteries that power the alarm system can become depleted without the knowledge of the nurse, and maintenance personnel must be relied on to insure that the batteries are always adequate. The result is that nurses do not fully trust the alarm system. This results in closer surveillance by the nurses and, correspondingly, requires more of their time. In addition, there have been reported cases in which patients have died when respirators with faulty alarms became inoperative before medical personnel had become aware of the situation. As a result, a separate alarm system is desired, independent of the respirator alarm, which can sense when a patient is not being respired. It is desired that the alarm be attached to the patient and monitor some parameter that is a direct index of whether the patient is being respired or not. Sensing of even a mechanical parameter, such as change in volume of the chest with respiration, would be acceptable.

Requirements and Specifications

The alarm unit must be reliable. It must be sensitive enough to detect loss of respiration, but it must not be so sensitive that frequent false alarms are given. If frequent false alarms are given, the unit will be turned off or ignored, and it will serve no useful purpose. Necessary attachments to the patient must not be so bulky as to cause the patient discomfort. In summary, simplicity, reliability, and low false alarm rate are primary requirements.

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P R O B L E M S T A T E M E N T

"Waste Management Technique"

What is Needed

A waste management system suitable for use with paraplegics is desired.

Background

An extremely difficult problem in the care of persons with lower extremity paralysis is safe, convenient waste management. There are several significant factors which more than justify the need for improved waste management techniques without even considering the matter of hygiene and convenience. First, many of these patients have the ability and qualifications to hold down profitable employment positions and to become effective contributors to society if effective waste management techniques were available. Second, compactions of fecal matter in the bowels is a recurring and severe problem with these patients. Indeed, death resulting from complete blockage is not unknown.

Basically, waste management in these cases involves some combination of the following requirements:

(1) A collection and temporary storage device for urine that can be worn by the patient during daily activities.

a. The configuration of the urine collection device must be such that the leakage does not occur at the interface between the patient and the device.
b. The urine collection device will likely require different configurations for male and female because of anatomical differences.

(2) A solid waste collection and temporary storage device that can also be worn by the patient during daily activities.

a. The most severe requirement on the solid waste collection device occurs for patients with no muscle control and no ability to void. For these patients, an "active" collection device is required; i.e., the device must extract the fecal matter.
b. Although not necessary, a common waste storage unit could be employed for the liquid and solid waste on those patients requiring both.

Requirements and Specifications

The unit must be comfortable enough to be worn fourteen hours by the patient. The necessity for small size can be readily appreciated. The capacity of the storage unit(s) must be sufficient to store at least 1,000 cubic centimeters of liquid and 150 cubic centimeters of solid waste. Leakage is a severe psychological problem and to be acceptable to the patient such "accidents" must be reduced to the point that the patient has confidence in the units. Zero leakage is desirable. Of course, the greatest leakage problem is not with the storage unit, but rather with the interface between the patient and the collection unit.

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P R O B L E M S T A T E M E N T

"A Means of Presetting Prosthetic Hands to Grip Objects With a Desired Force"

What is Needed

A means of causing prosthetic hands to grip an object with a prescribed force is needed

Background

Powered prosthetic hands that are commonly available today grasp objects with a fixed force which is frequently either not adjustable or very difficult to adjust. Various devices have been tried. For example, slip clutches are sometimes incorporated in the drive train so that, when the hand grasps an object, the drive continues to close the hand until the force which corresponds to the slip clutch is exceeded. At that point, the clutch slips, and the force applied by the hand remains constant. Unfortunately, in rehabilitation it is desirable (because of the varying tasks that different people perform) that different prosthetic hands be capable of adjustment to provide different grasping forces. This is not easily accomplished with the slip clutches in use. In addition, the slip clutches themselves add mechanical complexity and expense to the hand. Other techniques have been tried, but most suffer from complexity, difficulty of adjustment, or high cost. What is desired is a very simple means of controlling the grasp of a prosthetic hand so that its grasping force does not exceed a prescribed limit.

Requirements and Specifications

The primary requirements placed on the solution to this problem are simplicity and low cost. Complexity and accompanying bulk will discourage use. In the clinical situation, even moderately high cost will positively prohibit use. In addition, the installation of the necessary control circuitry or device must be relatively easily accomplished to permit retrofitting to existing prosthetic hands. Further, the method of control selected must permit changing of the preset grasping force quickly and easily should the requirements of the prosthetic hand user change.

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P R O B L E M S T A T E M E N T

"EMG Telemetry for Hand Therapy"

What is Needed

A small telemetry unit which can be strapped to a patient's arm and used to transmit the electromyographic signal from a muscle on the hand is required.

Background

The Hand Rehabilitation Center of the University of North Carolina Medical School is engaged in a program of occupational and physical therapy to help in restoring the function of the hand to people who have received injuries that cause incapacitation. Therapy is also administered to regain function of hands where surgical corrective procedures have been accomplished.

One important aspect of therapy is the fact that it is desirable to exercise certain particular muscles in specific fashions, in order to strengthen or regain function in these muscles. Damaged muscles are frequently favored by bringing into play some other combination of muscles to produce the motions prescribed by the therapy. As a result, a method is required to determine if the specific muscle involved is actually being exercised.

In the past, the Hand Rehabilitation Center has used a simple electromyographic (EMG) device which picks up the EMG signal from the specific muscle that is being exercised. Electromyography is a general term which includes any procedure for registering the electrical activity of muscle. A simple way to detect the electrical activity or action potentials of skeletal muscle is to place surface electrodes on the skin over the muscle. No electrical activity occurs over the resting muscle. During muscle contraction, an irregular oscillation of 0.1-2 millivolts, often with a frequency of about 50 hertz, occurs. Electrical activity is an indication of voluntary or reflex contraction of the muscle, and the electrical signal magnitude is approximately proportional to the tension produced by the muscle. Thus, the magnitude of the signal can be used as an index of the neuromuscular activity of the muscle being monitored.

While this device has been of great help, it has a number of limitations. First, the EMG amplifier requires the constant presence of an operator. Second, during the therapy sessions it is sometimes necessary for the patient to move from one exercise device to another. Because of the necessity to carry the EMG amplifier from place to place, it is not often used in this manner. Essentially, patients are not monitored as they perform the various exercises because of the inconvenience in carrying the unit from place to place. A small EMG telemetry unit that could be strapped to the patient's arm or wrist would permit monitoring of the EMG signal from the selected muscle as the patient goes through his entire therapy session. Constant attendance of a therapist would not be required, thus permitting therapists to treat more patients.

Requirements and Specifications

The telemetry transmitter must be small enough to strap on the arm or wrist. Dimensions of 1 inch by 2 inches would not be prohibitive, although a smaller unit would be more desirable. Rechargeable batteries are also desirable. Batteries should permit operation of the unit for 8 hours without recharging. Sensitivity of the unit should be sufficient to detect EMG signals as low as 0.01 millivolt since the EMG output from damaged muscles is frequently lower than the normal values. The transmission range required is less than 30 feet. The receiver should have provision for coupling to a standard strip chart recorder, as well as an audio output. Simultaneous or individual selection of these ourputs is desired.

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P R O B L E M S T A T E M E N T

"Non Contacting Method for Human Infant Position Determination"

What is Needed

A means is needed for automatically recording position vs. time for a 10-month old infant crawling freely in a closed room.

Background

Dr. Rheingold's long-term goal is understanding the development of social and exploratory behavior in the human infant. Her research program directed toward this end has practical implications in the guidelines it may provide for child raising and training, surely a subject of universal interest, but the primary value of this research lies in its basic contributions to the science of developmental psychology, a science still in relative infancy.

Dr. Rheingold and her associates are now studying infant-mother detachment, the process by which the dependent infant moves toward independence. Detachment may be contrasted to the more familiar (but not directly opposite) concept of attachment--the infant is attached to his mother, to other family members, to places and objects. Detachment is as universal as attachment and as important, but less well studied.

Detachment and exploratory behavior are intimately related; the child leaves the mother to explore his surroundings, his environment. How does the child explore his environment and acquire information about it? How does this behavior change when one changes the environment? And adding a toy or two to a previously empty room is an example of a change in environment from the child's viewpoint. How often does the child return to contact the mother? What does he look at and for how long? How does this change with age? These and other seemingly commonplace questions must be given answers by experiment, and Dr. Rheingold's group has been making experimental observations on the exploratory behavior of 10-month old infants.

The 10-month old infant is placed in a closed room. Toys are present in some cases, not in others. In the work up to this point the mother has been present, seated at one point in the room. Pairs of trained observers, viewing from outside the room, watch the infant's responses according to preselected criteria. Responses used have included the child's position in the room, how often the child looks at a toy, how often at the mother, and the frequency of contact with the toy or mother. The child's sounds are also tape-recorded.

One of the most important measures of exploratory behavior is the record of the child's position vs. time. It is highly desirable to record this automatically, both to lighten observer load and to remove psychological bias from the observation. (This bias is the reason pairs of observers are used.) A

difficulty is that the free child's natural exploratory behavior is the goal, and no measuring system can be used which would interfere with that behavior.

Requirements and Specifications

At present, the position of the 10-month old child in the experimental room is recorded by observers watching through one-way glass mirrors in one wall of the closed room. The observers record the time when the child crosses grid lines marked on the floor; the lines are roughly three feet apart defining cells about one square yard in area.

The experimental room is rectangular, about 9 feet wide by 18 feet long. Walls and ceiling are off-white and concealed incandescent lights on one of the longer walls provide approximately 7 foot-candles of illumination at the floor. One-way mirrors in one wall give a view of the room for the experimental observers. The room is empty except for the child and a few toys; in some experiments the mother will also be present, seated and relatively motionless at one end of the room.

An important constraint is that nothing can be attached to the child or to the child's clothing. Even if a lightweight light source or reflector could be put on the clothing for some type of optical tracking scheme, the child could lie down or otherwise be oriented in a position such that the point being tracked was out of sight of the tracking system. However, the child could wear some clothing color providing optical contrast to the rest of the room if this were useful.

Since only motion in the horizontal plane is involved, it may be possible to instrument the floor (at present asphalt tile) to record the child's position. Whatever method is used must be reliable and relatively simple as it is to be operated and maintained by psychologists and their technician.

The accuracy of position determination required is about a foot in each of the two dimensions. The researchers already use a digital data acquisition system which can record 64 event-vs.-time channels on an incremental magnetic tape recorder. At least 10 channels are not in use allowing the possibility of a 5-bit binary code for each of the two dimensions specifying child position; 5 bits will allow sufficient accuracy. Whatever method is used for the automatic recording of the child's position vs. time will ultimately be connected to this data acquisition system.

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P R O B L E M S T A T E M E N T

"Improved Mechanical Respirators"

What is Needed

An improved method of providing artificial respiration for polio victims is required.

Background

Poliomyelitis is a virus infection which can result in varying degrees of paralysis including total paralysis of the body except for the head and neck. The incidence of poliomyelitis has been dramatically reduced by the use of a vaccine, but many of the victims of the epidemics of 1945-55 are still surviving with the aid of mechanical respirators. About 1500 of these victims are confined to "iron lungs" and improvements in these units are required.

Artificial respiration can be produced by applying a positive pressure or a negative pressure on the outside of the chest. The positive pressure method cannot be used for significant periods of time because of the resulting constrictions in the cardiovascular system. Positive pressure can be applied for brief periods on the inside of the lungs, but this method is unsuitable because the patient cannot talk adequately.

Most suitable respiration methods use a negative pressure on the chest wall and various configurations exist for applying this pressure. The most familiar configuration is the tank respirator or "iron lung" which is simply a cylinder that encloses the patient from the neck to the feet. A moving piston produces a periodic negative pressure.

Another configuration for applying a negative pressure is the cuirass or "peanut shell" type which is simply a shell that fits over the top of the chest and a negative pressure is applied to the shell. This negative pressure provides the required seal between the shell and the chest as well as the force for moving the chest wall.

The tank respirators provide the best lung ventilation, but they are very bulky and confine the patient to a horizontal position. This means that the patient finds it very difficult to perform simple tasks such as turning pages of a book (with a stick held in the mouth) and using a typewriter (with a stick also). The patient has no mobility, and also finds it difficult to remove nasal congestion which is quite prevalent.

Many of the problems can be solved if the patient can simply sit up. The cuirass units enable the patient to sit up and allow a fair degree of mobility in a wheel chair. Patients can travel and perform simple tasks which enable them to take a more active and useful role in society. Unfortunately, the cuirass

units are about 30-50 percent as efficient in providing air to the lungs so that only very limited use can be made of these units.

The basic problem is to provide a method of lung ventilation that has the efficiency of the tank unit and the flexibility and portability of the cuirass units. It appears that in order to provide adequate ventilation, a total enclosure of the chest is required. Thus the new configuration should provide a means of enclosing the chest from the neck to the hip, provide an adequate seal for low negative pressures, and provide a flexibility such that a patient can sit up as well as lie down.

Requirements and Specifications

A negative pressure of from 0-40 centimeters of water is required. A breathing rate of about 15-20 times per minute is typical with an exchange of air in the lungs of about one liter per breath. Thus the exchange of air in the enclosure shell will be about 2 liters.

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P R O B L E M S T A T E M E N T

"High Intensity, Soft X-Ray Sources"

What is Needed

A high-intensity, soft X-ray source is needed.

Background

Roentgen or X-rays are widely used in medicine for a variety of purposes ranging from tissue destruction for therapeutic purposes to visualization of structures within the human body for diagnostic purposes. A variety of sources from radioactive materials to electronic X-ray generators are employed. The X-radiation derived from these sources covers a broad band of wavelengths. In electronic X-ray generators, the wavelength is a function of the voltage applied to the X-ray tube. Typical values of wavelength and equivalent tube voltage for various applications are listed below.[1]

Application	kV	Wavelength Å
Superficial therapy	5-10	5.0 - 2.5
General roentgenography	30-100	0.80- 0.24
Immediate therapy	140	0.18
Deep therapy	200-400	0.12- 0.06
Supervoltage therapy	> 1000	< 0.02

Generally speaking, the higher the voltage (shorter wavelength), the more penetrating the radiation. The more penetrating the radiation, the more difficult it is to detect subtle differences in tissue or structure density. For example, with the high voltage X-ray sources, all tissue is essentially transparent to the radiation and only dense bony structures can be differentiated. On the other hand, as the voltage is lowered, smaller differences in density of tissues can be detected.

The researcher is interested in the use of X-rays to detect tumors in soft tissue. The specific application is mammography, i.e., the taking of X-ray photographs of the female breast, for the purpose of detecting tumors. Differentiation of tumors from normal tissue in the female breast with X-rays requires low voltage (long wavelength) X-ray sources in the range of 20-35 kV peak. There are X-ray sources available in this voltage range, but there is one significant difficulty.

In order to achieve the tissue discrimination necessary to detect these tumors, very subtle differences in density on the exposed film must be evaluated. Available X-ray sources in this voltage range have a low energy output, so that relatively long exposures are required to obtain a usable

[1] Medical Physics, Otto Glasser, Vol. 1, p. 1397, The Year Book Publishers, Inc., 1944.

image on film. Using the fastest, commercially available high-resolution film, exposures in excess of six seconds are required. (It should be noted that faster X-ray films are available, but their resolution is insufficient for these purposes.) Of course, in such a long exposure it is impossible to eliminate internal (and external) motion of the patient as a result of respiration and heartbeat. This movement results in blurred images which render tissue discrimination all but impossible. To overcome this difficulty, a higher energy, low voltage X-ray source is desired.

Requirements and Specifications

A high-intensity, low voltage X-ray source is desired. The source should be in the range of 20-35 kilovolts peak. The exposure time desired to reduce movement artifact on the film is one-tenth second. It is expected that a beam current in the order 10 amperes will be required.

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P R O B L E M S T A T E M E N T

"Freezing Unit for Smallpox Vaccine"

What is Needed

A portable self-powered freezing unit for storing smallpox vaccine in remote, tropical regions.

Background

Smallpox is a highly contagious disease which can result in permanent disfigurement and death. The World Health Organization has set a goal of eradicating smallpox from the earth by 1977 and, to reach that goal, massive vaccination programs are underway. The program is particularly active in Africa because the disease is endemic in the tropics.

Smallpox vaccine must be stored at $0^{o}C$ from the time of production to the time of administration to the patient. This degree of temperature control is particularly difficult in the remote regions of tropical Africa. The vaccine must be transported by truck to the remote regions, and the vaccine must be stored in portable truck-borne freezers for periods up to 20 days. Several types of units have been tried but all have been unsatisfactory. Kerosene-operated units have not been mobile enough and thermoelectric units have not provided adequate cold. It may be possible to use LP gas-operated units if reliable units can be found.

Requirements and Specifications

The constraints on weight and size of the freezer are approximately 150 pounds and 30 inches x 30 inches x 30 inches, with a 2.5-3 cubic foot capacity. Internal temperatures of $0^{o}C$ must be maintained in remote areas for 20 days in regions where the ambient temperature is $38^{o}C$.

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P R O B L E M S T A T E M E N T

"Urination Detection"

What is Needed

A transducer is needed to detect the onset of urination by geriatric patients.

Background

One of the significant problems facing the National Institute of Mental Health is concerned with geriatric patients (patients over the age of 65). A frequent problem with these patients is incontinence of urine (the inability to control urination) and the lack of realization by the patient that urination has occurred. As an example of the extent of this problem, in one Veterans Administration hospital over 200 of the 2000 patients were incontinent, and the staff time and effort required to keep the patients dry significantly reduces the staff time available for activities such as group therapy or occupational therapy.

It is believed that if the nursing staff could be made aware of the onset of urination by patients, the patients can be trained to respond to the sensation of a full-bladder by promptly taking them to the bathroom; this procedure has been effective with children who wet the bed.

A transducer is required for detecting the onset of urination. If an appropriate transducer can be found. The output of the transducer will be telemetered to a central nursing station.

Requirements and Specifications

The patients wear cotton work pants with no underclothing, and it will be possible to measure moisture in the pants without requiring a direct attachment to the genitals. The transducer must be small and lightweight because the patients are generally confused and might not tolerate bulky equipment strapped to them. Total weight of the transducer must be on the order of ounces.

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APPENDIX E

E.1 Potential Biomedical Industries for Participation in Biomedical Technology Transfer

1. Electrocardiographic Equipment
2. Blood Systems
3. Medical Electrodes & Implants
4. Physiological Equipment
5. Artificial Kidney Equipment
6. Pulmonary Equipment
7. Surgical Tools
8. Tissue & Membrane Equipment
9. Radioactive Chemicals & Equipment
10. Optical Instruments
11. Acoustical Instruments
12. Special Foods & Diets
13. Disposable Supplies
14. Remote Handling Equipment
15. Electronic Support Equipment
16. Telemetry Equipment
17. Graphic & Analog Computational Equipment
18. General Instrument Companies

E.2. Partial Listing of Biomedical Equipment Manufacturers

1. ELECTROCARDIOGRAPHIC EQUIPMENT

Astro-Space Laboratories, Inc.; Huntsville, Alabama
Biocom, Inc.; Culver City, California
C. & G Medtronics; Albuquerque, New Mexico
Carolina Medical Electronics, Inc.; Winston-Salem, North Carolina
Medical Technology Corp.; South Dallas, Texas
Medical Technology, Inc.; Waltham, Massachusetts
M.D. Electronics, Inc.; Burbank, California
Siemens Medical of America, Inc.; Addison, Illinois

2. BLOOD SYSTEMS

Avionics Research Products Corp.; Los Angeles, California
Beta Corp. of St. Louis; St. Louis, Missouri
Bio Medical Systems, Inc.; Danbury, Connecticut
Medical Systems Corp.; Great Neck, New York
Metro Physics, Inc.; Santa Barbara, California
Micro Instruments, Inc.; Los Angeles, California
Nebraska Medical Instruments, Inc.; Omaha, Nebraska
Oxford Instrument Co.; Jackson, Mississippi
Payton Associates, Inc.; Buffalo, New York
Quinton Instruments; Seattle, Washington
Texas Medical Instrument Corp.; Houston, Texas

3. MEDICAL ELECTRODES & IMPLANTS

Bio-Engineering Consultants, Inc.; Ann Arbor, Michigan
Extracorporeal Medical Specialties, Inc.; Mt. Laurel Township, New Jersey
Medwire Corp.; Mt. Vernon, New York
Medtronic, Inc.; Minneapolis, Minnesota
Polysciences, Inc.; Warrington, Pennsylvania
Surgitool Incorporated; Pittsburg, Pennsylvania

4. PHYSIOLOGICAL EQUIPMENT

Bio-Medical Electronics, Inc.; Rockville, Maryland
Bio-Medical Instrument Co.; Newbury, Ohio
Electrodyne, Div., of Becton, Dickinson & Co.; Westwood, Massachusetts
Gulton Industries; Willow Grove, Pennsylvannia
Marietta Apparatus Co.; Marietta, Ohio
Physiological Training Co.; San Marino, California

5. ARTIFICIAL KIDNEY EQUIPMENT

Bio/Systems, Inc.; Santa Monica, California
Kumion Crafts, Inc.; Arden, Delaware
Myron L. Co.; San Gabriel, California
Roy, Milton, Co.; St. Petersburg, Florida
Seattle Artificial Kidney Supply Company; Seattle, Washington
Sigmamotor, Inc.; Middleport, New York
Travenol Laboratories, Inc.; Morton Grove, Illinois

6. PULMONARY EQUIPMENT

Donti Research Development Mfg. Corp.; Monsey, New York
Electro/Med Instruments, Inc.; Houston, Texas
Med-Science Electronic, Inc.; St. Louis, Missouri
Stile-Craft Manufacturers, Inc.; St. Louis, Missouri

7. SURGICAL TOOLS

Foredom Electric Co.; Bethel, Connecticut
Frigitronics, Inc.; Bridgeport, Connecticut
Mueller, V., Div., American Hospital Supply Corp.; Chicago, Illinois
Zimmer Manufacturing Co.; Warsaw, Indiana

8. TISSUE & MEMBRANE EQUIPMENT

Flow Laboratoreis, Inc.; Rockville, Maryland
Spider, Inc.; Sudbury, Massachusetts

9. RADIOACTIVE CHEMICALS & EQUIPMENT

American Nuclear Corp.; Oak Ridge, Tennessee
New England Nuclear; Boston, Massachusetts

10. OPTICAL INSTRUMENTS

Bauch & Lomb Inc.; Rochester, New York
Biometrics, Inc.; Cambridge, Massachusetts
National Statham, Inc.; Elmhurst, New York
Space Sciences, Inc.; Waltham, Massachusetts
Spectronics Corp.; Westbury, New York

11. ACOUSTICAL INSTRUMENTS

Listening, Inc.; Arlington, Massachusetts
Medrad, Inc.; Pittsburg, Pennsylvania
Unirad Corp.; Aurora, Colorado

12. SPECIAL FOODS & DIETS

General Biochemicals; Chagrin Falls, Ohio
Worthington Biochemical Corp.; Freehold, New Jersey

13. DISPOSABLE SUPPLIES

Concept, Inc.; St. Petersburg, Florida
Kimberly-Clark Corp.; Neenah, Wisconsin

14. REMOTE HANDLING EQUIPMENT

Baird Atomic, Inc.; Cambridge, Massachusetts
Central Research Laboratories, Inc.; Red Wing, Minnesota
Del Mar Engineering Laboratories; Los Angeles, California
Eberline Instrument Corp.; Santa Fe, New Mexico

15. ELECTRONIC SUPPORT EQUIPMENT

Airborne Instruments Lab.; Deer Park, New York
American Electronics, Inc.; Fullerton, California
Fairchild Camera & Instrument Corp.; Clifton, New Jersey
Helena Laboratories; Allen Park, Michigan
Medical Instruments, Inc.; Portland, Oregon
3M Co., Medical Products Div.; St. Paul, Minnesota
Savant Instruments Inc.; Hicksville, L. I., New York
Sylvania Electric Products, Inc.; Bedford, Massachusetts

16. TELEMETRY EQUIPMENT

Biocom Inc.; Culver City, California
Medintron Corp. of America; New York, New York
Signatron Inc.; Gardena, California

17. GRAPHIC & ANALOG COMPUTATIONAL EQUIPMENT

Adage, Inc.; Boston, Massachusetts
Crane Bio-Medical Instruments, Inc.; Elmont, New York
Instrumentation Specialties Co., Inc.; Lincoln, Nebraska
Kollmorgen Color Systems; Attleboro, Massachusetts

18. GENERAL INSTRUMENT COMPANIES

Artronix Instrumentation; St. Louis, Missouri
Bioelectric Instruments, Inc.; Yonkers, New York
Bionic Instruments, Inc.; Bala-Cynwyd, Pennsylvania
Buchler Instruments, Inc.; Lee, New Jersey
Electronics for Life Sciences, Inc.; Ile, Maryland
Gilson Medical Electronics, Inc.; Middleton, Wisconsin
Hall Associates; Santa Barbara, California
In Vivo Metric Systems; Los Angeles, California
Medics Instrument Corp.; Brooklyn, New York